

# PART 4

R-134a R-22  
Refrigerants, Brines, Oils





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## PART 4 REFRIGERANTS, BRINES, OILS

### SYSTEM DESIGN MANUAL

#### SUMMARY OF PART FOUR

This part of the System Design Manual presents data to guide the engineer in the application and selection of refrigerants, brines and oils when used with air conditioning system.

The text of this Manual is offered as a general guide for the use of industry and of consulting engineers in designing systems. Judgment is required for application to specific installation, and Carrier is not responsible for any uses made of this text.

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## CHAPTER 1. REFRIGERANTS

This chapter provides information concerning the refrigeration cycles and characteristics of the commonly used refrigerants and their selection for use in air conditioning applications.

To provide refrigeration, a refrigerant may be utilized either:

1. In conjunction with a compressor, condenser and evaporator in a compression cycle, or
2. With an absorbent in conjunction with an absorber, generator, evaporator, and condenser in an absorption cycle.

The refrigerant absorbs heat by evaporation generally at a low temperature and pressure level. Upon condensing at a higher level, it rejects this heat to any available medium, usually water or air.

In a compression system the refrigerant vapor is increased in pressure from evaporator to condenser pressure by the use of a compressor.

In an absorption system the increase in pressure is produced by heat supplied from steam or other suitable hot fluid which circulates thru a coil of pipe. The absorber-generator is analogous to a compressor in that the absorber constitutes the suction stroke and the generator the compression stroke. The evaporator spray header corresponds to the expansion valve. The evaporator and condenser are identical for both compression and absorption systems.

This chapter includes a discussion of the refrigeration cycle, refrigerant selection, and the commonly used refrigerants as well as tables indicating their characteristics and properties.

### REFRIGERATION CYCLES

#### ABSORPTION CYCLE

The absorption refrigeration cycle utilizes two phenomena:

1. The absorption solution (absorbent plus refrigerant) can absorb refrigerant vapor.
2. The refrigerant boils (flash cools itself) when subjected to a lower pressure.

These two phenomena are used in the lithium bromide absorption machine to obtain refrigeration by using the bromide as an absorbent and water as a refrigerant.

Water is sprayed in an evaporator which is maintained at a high vacuum. A portion of the water flashes and cools that which remains. The water vapor is absorbed by a lithium bromide solution in the absorber. The resulting solution is then heated in the generator to drive off the water vapor which is condensed in the condenser. The water is returned to the evaporator, completing the cycle.

*Figure 1* illustrates the absorption cycle. *Figure 2* illustrates the cycle plotted on the equilibrium diagram with numbered points representing pressures, temperatures, concentrations in the cycle.

On the lower left side of *Fig. 1* is the absorber partially filled with lithium bromide solution. On the lower right side is the evaporator containing water. A pipe connecting the shells is evacuated so that no air is present. The lithium bromide begins to absorb the water vapor; as the vapor is absorbed, the water boils, generating more vapor and causing the remainder of the water to be cooled.

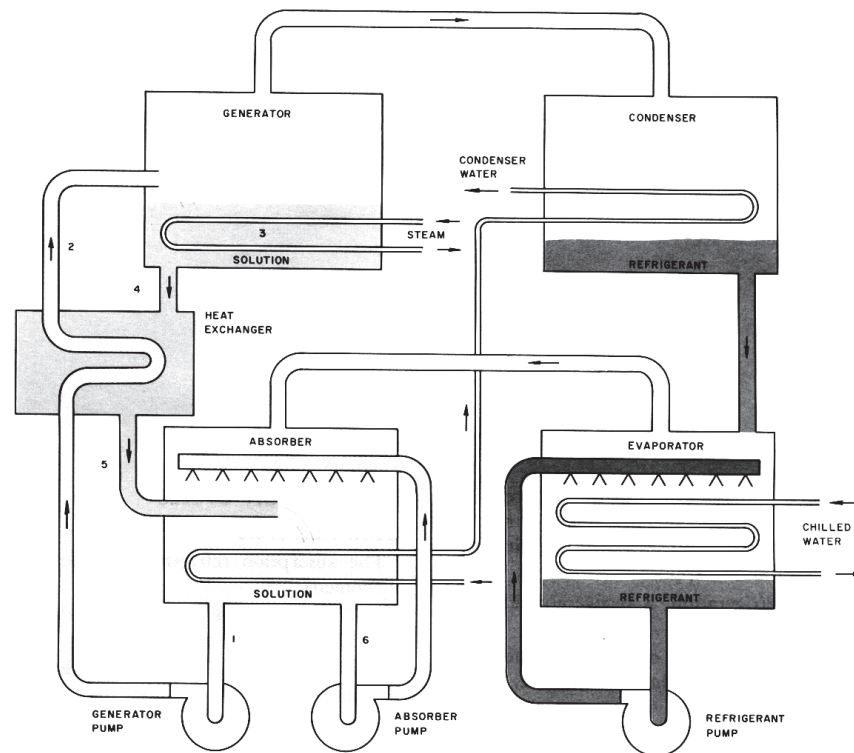


FIG. 1-ABSORPTION REFRIGERATION CYCLE

Since the water can vaporize more easily if it is being sprayed, a pump is used to circulate the water from the bottom of the evaporator to a spray header at the top. An evaporator tube bundle is located under the evaporator spray header; water inside the tubes, returning from the air conditioning coils or other load, is flash-cooled by the water on the outside of the evaporator tubes. The lithium bromide solution absorbs water vapor easier if it is sprayed; therefore, a pump is used to circulate the solution from the bottom of the absorber to a spray header at the top of absorber.

As the lithium bromide continues to absorb water vapor, it becomes diluted, and its ability to absorb additional water vapor decreases. The weak solution is

pumped to the generator where heat is applied by steam or other suitable hot fluid in the generator tube bundle to boil off the water vapor. The solution is concentrated and returned to the absorber. Since the weak solution going to the generator must be heated and the strong solution coming from the generator must be cooled, a heat exchanger is used in the solution circuit to conserve heat.

Water vapor boiled from the solution in the generator passes to the condenser to contact the relatively cold condenser tubes. The vapor condenses in the condenser and returns to the evaporator so that there is no loss of water in the cycle. Before the condenser water goes thru the condenser tubes, it passes thru a tube bundle located in the absorber. Here it picks up the heat of dilution and the heat of condensation which is generated as the solution absorbs water vapor.

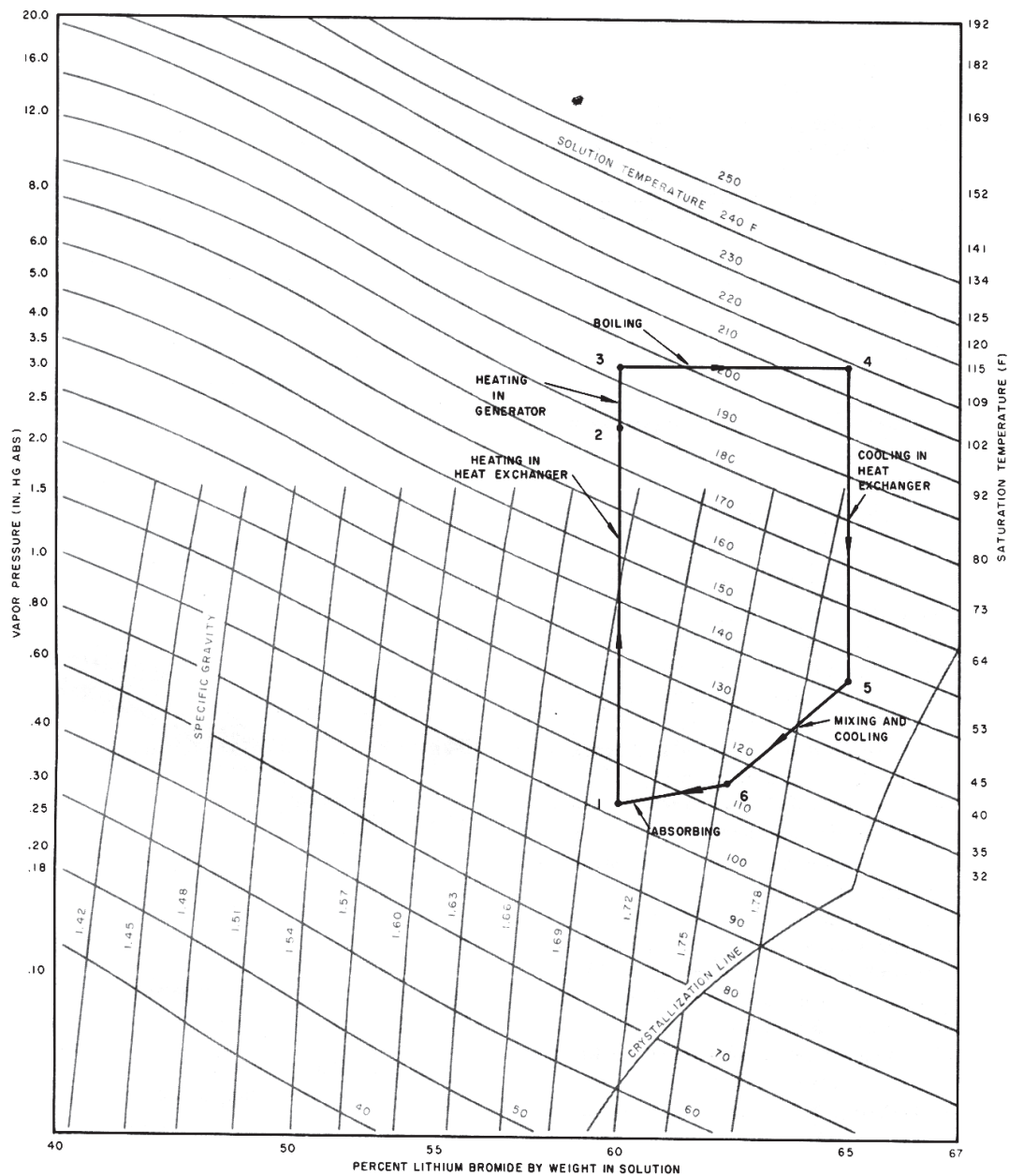


FIG. 2- EQUILIBRIUM DIAGRAM FOR LITHIUM BROMIDE

### COMPRESSION CYCLE

The compression refrigeration cycle utilizes two phenomena:

1. The evaporation of a liquid refrigerant absorbs heat to lower the temperature of its surroundings.

2. The condensation of a refrigerant vapor rejects heat to raise the temperature of its surroundings.

The cycle may be traced from any point in the system. *Figure 3* is a schematic and *Fig. 4* is a pressure-enthalpy diagram of a compression cycle.

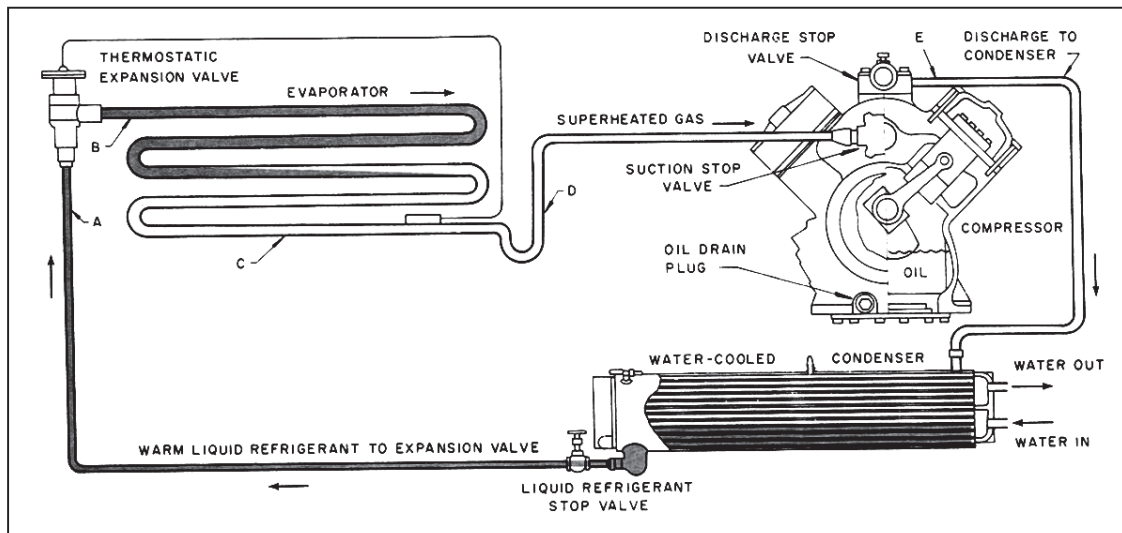


FIG. 3- RECIPROCATING COMPRESSION REFRIGERATION CYCLE

Starting with the liquid refrigerant ahead of the evaporator at point A in both Fig. 3 and 4, the admission of liquid to the evaporator is controlled by an automatic throttling device (expansion valve) which is actuated by temperature and pressure. The refrigerant pressure is reduced across the valve from condenser pressure, point A, to the evaporator pressure, point B. The valve acts as a boundary between the *high* and *low* sides of the system.

The pressure reduction allows the refrigerant to boil or vaporize. To support boiling, heat from the air or other medium to be cooled is transmitted to the evaporator surface and into the boiling liquid at a lower temperature. The refrigerant liquid and vapor passing thru the evaporator coil continues to absorb heat until it is completely evaporated, point C. Superheating of the gas, controlled by the expansion valve, occurs from C to D.

The superheated gas is drawn thru the suction line into the compressor cylinder. The downstroke of the piston pulls a cylinder of gas thru the suction valve and compresses it on the upstroke, raising its temperature and pressure to point E. The pressure produced causes the hot gas to flow to the condenser. The compressor discharge valve prevents re-entry of compressed gas into the cylinder and forms a boundary between the *high* and *low* sides.

In the condenser the condensing medium (air or water) absorbs heat to condense the hot gas. Liquid.

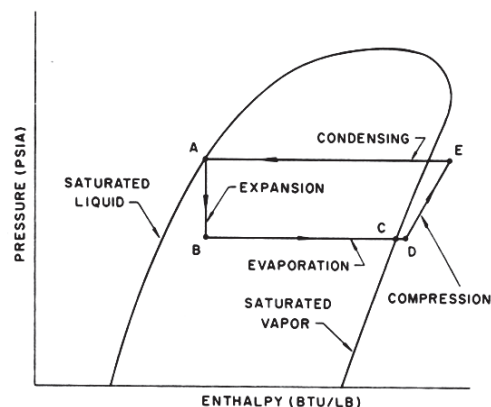


FIG. 4- PRESSURE-ENTHALPY DIAGRAM, COMPRESSION CYCLE

refrigerant is collected in receive which may be combined with or separate from condenser

The liquid is then forced thru the liquid line to the expansion valve A to repeat the cycle.

#### Liquid-Suction Interchangers

Compressor ratings for Refrigerants 12 and 500 are generally based on 65 F actual suction gas temperatures. When this suction gas temperature is not obtained at the compressor, its rating must be lowered by an appropriate multiplier. To develop the full rating, the required superheat which is over and above that available at the evaporator outlet may be obtained by a liquid-suction interchanger.



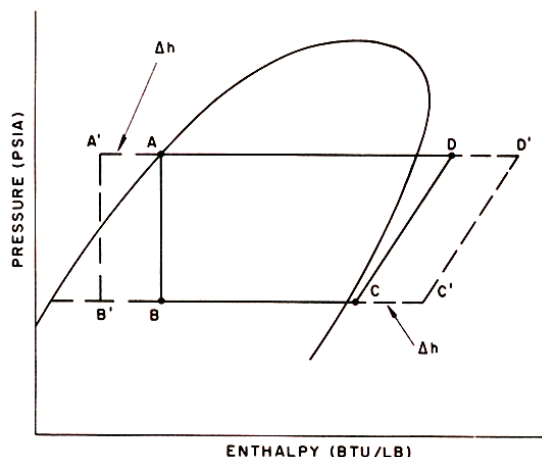


FIG. 5- EFFECT OF LIQUID-SUCTION INTERCHANGER ON COMPRESSION CYCLE

The effect of a liquid-suction interchanger on the refrigeration cycle is shown on the pressure-enthalpy diagram (Fig. 5).

The solid lines represent the basic cycle, while the dashed lines represent the same cycle with a liquid-suction interchanger. The useful refrigerating effect with an interchanger is B'C rather than BC as in the basic cycle.

Superheat increases the specific volume of the suction vapor to reduce the total weight of refrigerant circulated for a given displacement. It also increases the enthalpy of the vapor and may improve compressor volumetric efficiency. Provided the heat absorbed represents useful refrigeration such as liquid subcooling, the refrigerating effect per pound of refrigerant circulated is increased. With Refrigerants 22 and 717 volume increases faster than refrigerating effect; hence, superheating theoretically reduces capacity. With Refrigerants 12 and 500 the reverse is true, and superheating theoretically reduces both the cfm per ton and the power per ton. Figure 6 illustrates the loss due to superheating of the refrigerant vapor and the gain due to liquid subcooling. Net gain equals the gain minus the loss.

## REFRIGERANT PROPERTIES

Refrigerant characteristics have a bearing on system design, application and operation. A refrigerant is selected after an analysis of the required characteristics

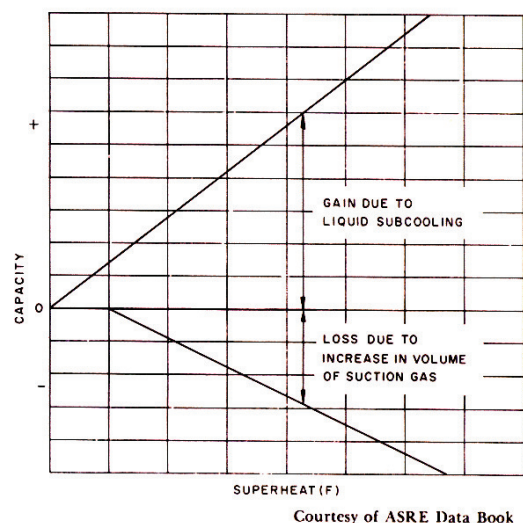


FIG. 6-EFFECT OF LIQUID-SUCTION INTERCHANGER ON CAPACITY

and a matching of these requirements with the specific properties of the available refrigerants.

Significant refrigerant characteristics are:

1. *Flammability and Toxicity* as they pertain to the safety of a refrigerant. The refrigerants treated in this chapter are classified in ASA B9.1 as Group 1, the least hazardous relative to flammability and explosiveness. The Underwriters' Laboratories classification with respect to toxicity puts these refrigerants in Groups 4 to 6. The higher numbered groups in this classification are the least toxic.

Figure 7 shows the structural formula of the refrigerant compounds treated in this chapter. The chlorine and fluorine elements in these refrigerants make them the least hazardous and least toxic respectively.

2. *Miscibility* of a refrigerant with compressor oil aids in the return of oil from the evaporator to the compressor crankcase in reciprocating machine applications. Centrifugal units have separate oil and refrigerant circuits.

Some refrigerants are highly miscible with compressor oil. Refrigerants 12 and 500 and lubricating oils are miscible in any proportion; Refrigerant 22 is less miscible. The effect of miscibility in a refrigeration system is illustrated in Fig. 8. If Refrigerant 12 is placed

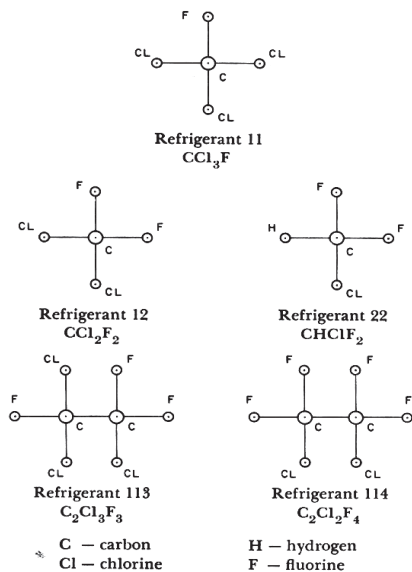


FIG. 7-STRUCTURAL FORMULAS FOR REFRIGERANTS

temperature, all of the refrigerant migrates to the vessel containing oil because of the absorption head of the oil. Raising the oil temperature limits this migration. For instance, if the oil is at an ambient temperature 20 degrees higher than the refrigerant or if the oil is heated by an immersion type heater to 20 degrees higher than the refrigerant temperature (Fig. 8b), only 67% of the oil weight of the refrigerant 20 degrees higher than the refrigerant becomes dissolved in the oil.

3. Theoretical *Horsepower* Per Ton of refrigeration for most refrigerants at air conditioning temperature levels is approximately the same (Table 1).
4. *Rate of Leakage* of a refrigerant gas increases directly with pressure and inversely with molecular weight. The pressure of a refrigerant for a given saturated temperature increases in the following order: Refrigerant 113, 11, 114, 12, 500, 22. The molecular weight of a refrigerant decreases in the following order: Refrigerant 113, 114, 11, 12, 500, 22. Molecular weight is directly related to vapor specific volume; the higher

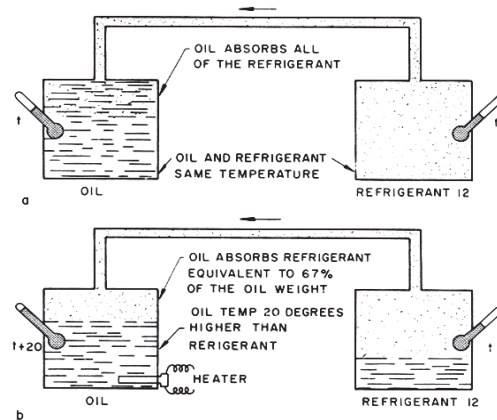


FIG. 8-MISCIBILITY OF REFRIGERANT 12 AND OIL.

The molecular weight, the higher the specific volume

5. *Leak Detection* of the refrigerant should be simple and positive for purposes of maintenance, cost and safety. The use of a halide torch makes it possible to detect and locate minute leaks of the halogen refrigerants.
6. *Vapor Density* influences the compressor displacement and pipe sizing. High vapor density accompanied by a reasonably high latent heat of vaporization (low cfm per ton) is desirable in a refrigerant. A low cfm per ton results in compact equipment and smaller refrigerant piping. Reciprocating refrigeration equipment requires a relatively high vapor density refrigerant for optimum performance. Centrifugal compressors require a low vapor density refrigerant for optimum efficiency at comparatively low tonnages. High vapor density refrigerants are used with centrifugals of large tonnage. The cfm per ton increases in the following order: Refrigerant 22, 500, 12, 114, 11, 113 (Fig. 9).

Cost which is usually a consideration in all selections should not influence the choice of a refrigerant since it generally has little economic bearing on the normal refrigeration system. Although Refrigerant 22 costs approximately twice as much as Refrigerant 12, the compressor required is smaller, tending to offset the additional cost of refrigerant.

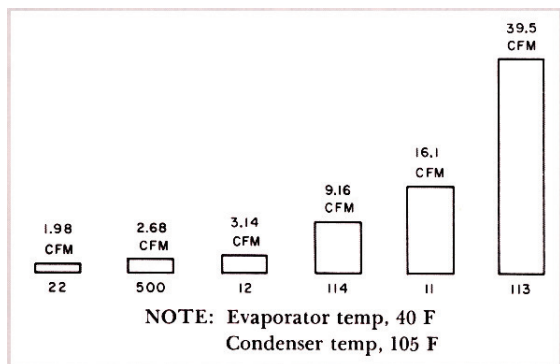


FIG. 9-SUCTION VOLUMES OF REFRIGERANTS  
(CFM/TON)

## HEAT TRANSFER COMPARISONS

The value of the evaporating and condensing film coefficient (Btu/sq ft/F) for Refrigerant 22 is greater than that for Refrigerants 12 and 500. However, it does not follow that cooling coils and condensers can, therefore, be rated for higher capacities with Refrigerant 22. The higher coefficient for Refrigerant 22 does not tell the complete story.

Various other factors should be considered:

1. Whether the heat exchanger is designed for either Refrigerant 22 or Refrigerants 12 and 500.
2. Whether heat transfer is between refrigerant and air or between refrigerant and water.
3. Whether tubes in a heat exchanger are prime surface or extended surface (including the amount of extended surface.)

The evaporating or condensing film coefficient is one of a number of factors which make up the total over-all transfer rate for the heat exchanger. Other factors involved are these:

1. Tube wall resistance (including extended surface, if any).
2. Air or water film coefficient.
3. Refrigerant pressure drop per circuit, which affects the mean effective temperature difference.
4. Surface ratio of tube outside surface to inside surface.
5. Fouling factors (water-cooled condensers).

## COOLING COILS

Cooling coils using Refrigerant 22 normally provide a greater capacity than those using Refrigerant 12 or 500. A cooling coil, normally, has considerable extended surface on the air side of the tubes. The higher

evaporating film coefficient of Refrigerant 22 combined with the extended surface results in a significant increase in the overall heat transfer rate.

When cooling coil is designed to permit a normal pressure drop with Refrigerant 22, it may have a rather large pressure drop with Refrigerant 12 or 500. In such a case the decreased performance for Refrigerants 12 and 500 is due partially to the difference in their condensing film coefficients. In addition, it is affected by the pressure drop and the resulting lower mean effective temperature difference.

## CONDENSERS

Water-cooled condensers using Refrigerant 22 normally provide a greater capacity than those using Refrigerant 12 or 500, depending on the fouling factor used in its selection. There are a number of reasons for this improvement other than the basically higher condensing film coefficient of the refrigerant.

1. The water film coefficient is relatively high as compared to air.
2. The extended surface or refrigerant side of the exchanger tubes assures maximum transfer rate and optimum balance between the inside and outside surfaces.

With Refrigerant 12 or 500 the performance of water-cooled condensers is otherwise not adversely affected since the pressure drop in the shell is not a consideration.

Air-cooled condensers using Refrigerant 22 normally provide a greater capacity than those using Refrigerant 12 or 500.

Air-cooled condensers have considerable extended surface on the air side of the tubes. The higher evaporating film coefficient of Refrigerant 22, combined with the extended surface results in a significant increase in the overall heat transfer rate.

When an air-cooled condenser is designed to allow for a normal pressure drop with Refrigerant 22, it may have a considerable pressure drop when used with Refrigerant 500 or 12. In such a case the decreased performance for Refrigerants 500 and 12 is not due entirely to the difference in their condensing film coefficients, but is affected also by pressure drop and the resulting lower mean effective temperature difference.

Normally, evaporative condensers use prime surface tubing (without extended surface on the outside of tubes). Where the unit is designed for Refrigerant 12 or 500, there is no significant increase in capacity when using Refrigerant 22.

If the unit is designed for Refrigerant 22 (smaller tubing or longer circuits), and is used with Refrigerant 12 or 500, the pressure drop is sufficient to reduce the rating. Such a design may create the impression that the increased rating for Refrigerant 22 is due to the condensing film, whereas actually the performance for Refrigerant 12 or 500 decreases due to coil design.

## REFRIGERANT SELECTION

### COMPRESSION CYCLE

The choice of a refrigerant for a compression system is limited by:

1. Economics,
2. Equipment type and size
3. Application

The manufacturer of the refrigeration compressor generally preselects the refrigerant to result in optimum owning cost. The specific refrigerant is determined by the type and size of the equipment.

To minimize the number of reciprocating compressor sizes required to fill out a line, the manufacturer rates each size for several refrigerants of relatively dense vapor such as Refrigerants 12, 500 and 22. In effect, this increases the number of units offered without adding sizes.

Centrifugal compressors at comparatively low tonnages require a high vapor volume refrigerant such as Refrigerant 113 or 11 to maintain optimum efficiency. For most sizes Refrigerant 114 or 12 can be used to obtain greater capacities. Refrigerants 500 and 22 are used with specially built centrifugals to obtain the highest capacities.

The refrigerant selected depends on the type of application. Air-cooled condensers may not use certain refrigerants because of the design condensing temperature required and corresponding limitations on compressor head pressure.

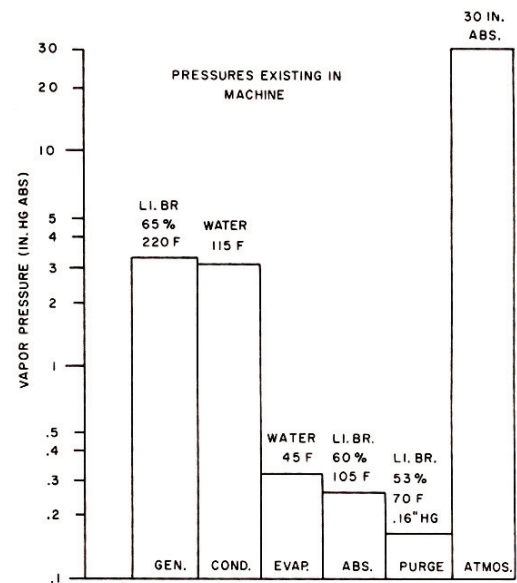
The temperature-pressure relationship of a refrigerant is of considerable importance in low temperature applications. If the evaporator pressure is comparatively low for the required evaporator temperature, the volume of vapor to be handled by the compressor is excessive. If the evaporator pressure is comparatively high for the required evaporator temperature, the system pressures are high.

The refrigerants that have been mentioned are the halogens (fluorinated hydrocarbon compounds), except for Refrigerant 500 which is an azeotropic mixture of two fluorinated hydrocarbons. The mixture does not separate into its component refrigerants with a change of

temperature or pressure. It has its own fixed thermodynamic properties which are unlike either of its components.

### ABSORPTION CYCLE

Water as a refrigerant and lithium bromide as an absorbent are utilized in the basic absorption refrigeration cycle. The refrigerant should possess the same desirable qualities as those for a compression system. In addition, it should be suitable for use with an absorbent, so selected that:



NOTE: Absorption machine at full load, using lithium bromide as absorbent.

FIG. 10-PRESSURES AND TEMPERATURES OF A TYPICAL ABSORPTION MACHINE

1. The vapor pressures of the refrigerant and absorbent at the generator are different.
2. The temperature-pressure relations are consistent with practical absorber and generator temperatures and pressures. *Figure 10* shows absolute pressures and temperatures existing in a typical absorption machine at full load.
3. The refrigerant has a high solubility in the absorbent at absorber temperature and pressure and a low solubility at generator temperature and pressure.
4. The refrigerant and absorbent together are stable within the evaporator-generator range of temperatures. Normally, the absorbent must remain liquid at



absorber and generator temperatures and pressures. It should have a low specific heat, surface tension and viscosity and must be neutral to the materials used in the equipment.

## REFRIGERANT TABLES

Table 1 is a tabulation of the various refrigerants and their characteristic. *Tables 2 to 7* list the properties of the refrigerants for various saturated temperatures.

**TABLE 1—COMPARATIVE DATA OF REFRIGERANTS**

| REFRIGERANT NUMBER<br>(ARI DESIGNATION)  | 11   | 12  | 22  | 113                                       | 114   | 500   | 502  |  |
|--|--|---|---|---|---|---|--|--|
| Chemical Name  | Trichloromono-<br>fluoromethane              | Dichlorodi-<br>fluoromethane              | Monochlorodi-<br>fluoromethane            | Trichlorotri-<br>fluoroethane             | Dichlorotetra-<br>fluoroethane                | Azeotrope of<br>Dichlorodi-<br>fluoromethane<br>and<br>Difluoroethane           | Azeotrope of<br>chlorodifluoro-<br>thane and M-<br>chloropent-<br>fluoroethane |  |
| Chemical Formula   | CCl <sub>3</sub> F                           | CCl <sub>2</sub> F <sub>2</sub>           | CHClF <sub>2</sub>                        | CCl <sub>2</sub> F-CClF <sub>2</sub>      | C <sub>2</sub> Cl <sub>2</sub> F <sub>4</sub> | 73.8% CCl <sub>2</sub> F <sub>2</sub><br>26.2% CH <sub>3</sub> CHF <sub>2</sub> | 48.8% CHCl <sub>2</sub><br>51.2% CClF <sub>2</sub>                             |  |
| Molecular Wt   | 137.38                                       | 120.93                                    | 86.48                                     | 187.39                                    | 170.93  | 99.29   | 111.64   |  |
| Gas Constant, R (ft-lb/lb-R)   | 11.25  | 12.78                                     | 17.87                                     | 8.25                                      | 9.04  | 15.57   | 13.87  |  |
| Boiling Point at 1 atm (F)   | 74.7   | -21.62                                    | -41.4                                     | 117.6                                     | 38.4  | -28.0   | -50.1  |  |
| Freezing Point at 1 atm (F)  | -168   | -252                                      | -256                                      | -31                                       | -137  | -254  | *  |  |
| Critical Temperature (F)   | 388.0  | 233.6                                     | 204.8                                     | 417.4                                     | 294.3   | 221.1   | 194.1  |  |
| Critical Pressure (psia)   | 635.0  | 597.0                                     | 716.0                                     | 495.0                                     | 474.0   | 631.0   | 618.7  |  |
| Specific Heat of Liquid, 86 F  | .220   | .235                                      | .335                                      | .218                                      | .238  | .300  | .305   |  |
| Specific Heat of Vapor, C <sub>p</sub><br>60 F at 1 atm  | *  | .146                                      | .149                                      | *   | .156  | .171  | .164   |  |
| Specific Heat of Vapor, C <sub>v</sub><br>60 F at 1 atm  | *  | .130                                      | .127                                      | *   | .145  | .151  | .161   |  |
| Ratio $\frac{C_p}{C_v}$ = K (86 F at 1 atm)  | 1.11   | 1.14                                      | 1.18                                      | 1.12                                      | 1.09  | 1.13  | 1.02   |  |
| Ratio of Specific Heats<br>Liquid, 105 F<br>Vapor, C <sub>p</sub> , 40 F sat. press.   | 2.04   | 1.55                                      | 2.14                                      | 1.47                                      | 1.59  | 1.77  | 1.97   |  |
| Liquid Head (ft), psi at 105 F   | 1.61   | 1.84                                      | 2.04                                      | 1.51                                      | 1.65  | 2.10  | 1.98   |  |
| Saturation Pressure (psia)<br>at: -50 F  | 0.52   | 7.12                                      | 11.74                                     | *   | 1.35  | 8.395   | 14.74  |  |
| 0 F  | 2.55   | 23.85                                     | 38.79                                     | 0.84                                      | 5.96  | 27.96   | 45.94  |  |
| 40 F   | 7.03   | 51.67                                     | 83.72                                     | 2.66                                      | 15.22   | 60.94   | 94.90  |  |
| 105 F  | 25.7   | 141.25                                    | 227.65                                    | 11.58                                     | 50.29   | 167.85  | 244.40   |  |
| Net Refrigerating Effect (Btu/lb)<br>40 F-105 F (no subcooling)  | 67.56  | 49.13                                     | 66.44                                     | 54.54                                     | 43.46   | 59.82   | 43.72  |  |
| Cycle Efficiency (% Carnot Cycle)<br>40 F-105 F  | 90.5   | 83.2                                      | 81.8                                      | 87.5                                      | 84.9  | 82.0  | 76.1   |  |
| Solubility of Water in Refrigerant<br>Miscibility with Oil<br>Toxic Concentration (% by vol)                                     | Negligible<br>Miscible<br>Above 10%          | Negligible<br>Miscible<br>Above 20%       | Negligible<br>Limited<br>Above 20%        | Negligible<br>Miscible<br>Above 5%        | Negligible<br>Miscible<br>Above 20%           | Negligible<br>Miscible<br>Above 20%   | 560 ppm @<br>Limited<br>Above 20   |  |
| Odor   | Ethereal,<br>odorless when<br>mixed with air | Same as R 11                              | Same as R 11                              | Same as R 11                              | Same as R 11                                  | Same as R 11  | Same as R  |  |
| Warning Properties<br>Explosive Range (% by vol)<br>Safety Group, U.L.<br>Safety Group, ASA B9.1<br>Toxic Decomposition Products | None<br>None<br>5<br>1<br>Yes                | None<br>None<br>6<br>1<br>Yes             | None<br>None<br>5A<br>1<br>Yes            | None<br>None<br>4-5<br>1<br>Yes           | None<br>None<br>6<br>1<br>Yes                 | None<br>None<br>5A<br>1<br>Yes  | None<br>None<br>5A when liq<br>1<br>Yes  |  |
| Viscosity (centipoises)<br>Saturated Liquid<br>Vapor at 1 atm  | 95 F<br>105 F<br>30 F<br>40 F<br>50 F        | .3893<br>.3723<br>.0101<br>.0103<br>.0105 | .2463<br>.2395<br>.0118<br>.0119<br>.0121 | .2253<br>.2207<br>.0120<br>.0122<br>.0124 | .5845<br>.5472<br>.0097<br>.0098<br>.0100     | .3420<br>.3272<br>.0108<br>.0109<br>.0111                                       | .2150<br>.2100<br>.0117<br>.0119<br>.0122                                      | .233<br>.225<br>.01175<br>.01202<br>.01225     |
| Thermal Conductivity (k)<br>Saturated Liquid<br>Vapor at 1 atm   | 95 F<br>105 F<br>30 F<br>40 F<br>50 F        | .0596<br>.0581<br>.0045<br>.0046<br>.0046 | .0481<br>.0469<br>.0047<br>.0049<br>.0051 | .0573<br>.0553<br>.0060<br>.0061<br>.0063 | .0512<br>.0500<br>.0037<br>.0039<br>.0040     | .0435<br>.0421<br>.0056<br>.0057<br>.0059                                       | .044<br>.042<br>.0041<br>.0043<br>.0045  | .03519<br>.03334<br>.00585<br>.00605<br>.00623 |
| Liquid Circulated, 40 F-105 F<br>(lb/min/ton)  | 2.96   | 4.07                                      | 3.02                                      | 3.66                                      | 4.62  | 3.35  | 4.58   |  |
| Theoretical Displacement,<br>40 F-105 F (cu ft/min/ton)  | 16.1   | 3.14                                      | 1.98                                      | 39.5                                      | 9.16  | 2.69  | 2.04   |  |
| Theoretical Horsepower Per Ton<br>40 F-105 F   | 0.676  | 0.736                                     | 0.75                                      | 0.70                                      | 0.722   | 0.747   | .80  |  |
| Coefficient at Performance<br>40 F-105 F (4.71/hp per ton)   | 6.95   | 6.39                                      | 6.29                                      | 6.74                                      | 6.52  | 6.31  | 5.86   |  |

TABLE 2-PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| -100        | 1.4280                  | 27.0138*  | 0.009985                 | 22.164                  | 100.15                     | 0.045119                  | -12.466                  | 78.714                    | 66.248                  | -0.032005                | 0.18683                 | -100        |
| -98         | 1.5381                  | 26.7896*  | .010002                  | 20.682                  | 99.978                     | .048352                   | -12.055                  | 78.524                    | 66.469                  | -.030866                 | .18623                  | -98         |
| -96         | 1.6551                  | 26.5514*  | .010020                  | 19.316                  | 99.803                     | .051769                   | -11.644                  | 78.334                    | 66.690                  | -.029733                 | .18565                  | -96         |
| -94         | 1.7794                  | 26.2984*  | .010037                  | 18.057                  | 99.627                     | .055379                   | -11.233                  | 78.144                    | 66.911                  | -.028606                 | .18508                  | -94         |
| -92         | 1.9112                  | 26.0301*  | .010055                  | 16.895                  | 99.451                     | .059189                   | -10.821                  | 77.954                    | 67.133                  | -.027484                 | .18452                  | -92         |
| -90         | 2.0509                  | 25.7456*  | 0.010073                 | 15.821                  | 99.274                     | 0.063207                  | -10.409                  | 77.764                    | 67.355                  | -0.026367                | 0.18398                 | -90         |
| -88         | 2.1988                  | 25.4443*  | .010091                  | 14.828                  | 99.097                     | .067441                   | -9.9971                  | 77.574                    | 67.577                  | -.025256                 | .18345                  | -88         |
| -86         | 2.3554                  | 25.1255*  | .010109                  | 13.908                  | 98.919                     | .071900                   | -9.5845                  | 77.384                    | 67.799                  | -.024150                 | .18293                  | -86         |
| -84         | 2.5210                  | 24.7884*  | .010128                  | 13.056                  | 98.740                     | .076591                   | -9.1717                  | 77.194                    | 68.022                  | -.023049                 | .18242                  | -84         |
| -82         | 2.6960                  | 24.4321*  | .010146                  | 12.226                  | 98.561                     | .081525                   | -8.7586                  | 77.003                    | 68.244                  | -.021953                 | .18192                  | -82         |
| -80         | 2.8807                  | 24.0560*  | 0.010164                 | 11.533                  | 98.382                     | 0.086708                  | -8.3451                  | 76.812                    | 68.467                  | -0.020862                | 0.18143                 | -80         |
| -78         | 3.0756                  | 23.6592*  | .010183                  | 10.852                  | 98.201                     | .092151                   | -7.9314                  | 76.620                    | 68.689                  | -.019776                 | .18096                  | -78         |
| -76         | 3.2811                  | 23.2409*  | .010202                  | 10.218                  | 98.021                     | .097863                   | -7.5173                  | 76.429                    | 68.912                  | -.018695                 | .18050                  | -76         |
| -74         | 3.4975                  | 22.8002*  | .010221                  | 9.6290                  | 97.839                     | .10385                    | -7.1029                  | 76.238                    | 69.135                  | -.017619                 | .18004                  | -74         |
| -72         | 3.7254                  | 22.3362*  | .010240                  | 9.0802                  | 97.657                     | .11013                    | -6.6881                  | 76.046                    | 69.358                  | -.016547                 | .17960                  | -72         |
| -70         | 3.9651                  | 21.8482*  | 0.010259                 | 8.5687                  | 97.475                     | 0.11670                   | -6.2730                  | 75.853                    | 69.580                  | -0.015481                | 0.17916                 | -70         |
| -68         | 4.2172                  | 21.3350*  | .010278                  | 8.0916                  | 97.292                     | .12359                    | -5.8574                  | 75.660                    | 69.803                  | -.014418                 | .17874                  | -68         |
| -66         | 4.4819                  | 20.7959*  | .010298                  | 7.6462                  | 97.108                     | .13078                    | -5.4416                  | 75.467                    | 70.025                  | -.013361                 | .17833                  | -66         |
| -64         | 4.7599                  | 20.2299*  | .010317                  | 7.2302                  | 96.924                     | .13831                    | -5.0254                  | 75.273                    | 70.248                  | -.012308                 | .17792                  | -64         |
| -62         | 5.0516                  | 19.6360*  | .010337                  | 6.8412                  | 96.739                     | .14617                    | -4.6088                  | 75.080                    | 70.471                  | -.011259                 | .17753                  | -62         |
| -60         | 5.3575                  | 19.0133*  | 0.010357                 | 6.4774                  | 96.553                     | 0.15438                   | -4.1919                  | 74.885                    | 70.693                  | -0.010214                | 0.17714                 | -60         |
| -58         | 5.6780                  | 18.3607*  | .010377                  | 6.1367                  | 96.367                     | .16295                    | -3.7745                  | 74.691                    | 70.916                  | -.009174                 | .17676                  | -58         |
| -56         | 6.0137                  | 17.6773*  | .010397                  | 5.8176                  | 96.180                     | .17189                    | -3.3567                  | 74.495                    | 71.138                  | -.008139                 | .17639                  | -56         |
| -54         | 6.3650                  | 16.9619*  | .010417                  | 5.5184                  | 95.993                     | .18121                    | -2.9386                  | 74.299                    | 71.360                  | -.007107                 | .17603                  | -54         |
| -52         | 6.7326                  | 16.2136*  | .010438                  | 5.2377                  | 95.804                     | .19092                    | -2.5200                  | 74.103                    | 71.583                  | -.006080                 | .17568                  | -52         |
| -50         | 7.1168                  | 15.4313*  | 0.010459                 | 4.9742                  | 95.616                     | 0.20104                   | -2.1011                  | 73.906                    | 71.805                  | -0.005056                | 0.17533                 | -50         |
| -48         | 7.5183                  | 14.6139*  | .010479                  | 4.7267                  | 95.426                     | .21157                    | -1.6817                  | 73.709                    | 72.027                  | -.004037                 | .17500                  | -48         |
| -46         | 7.9375                  | 13.7603*  | .010500                  | 4.4940                  | 95.236                     | .22252                    | -1.2619                  | 73.511                    | 72.249                  | -.003022                 | .17467                  | -46         |
| -44         | 8.3751                  | 12.8693*  | .010521                  | 4.2751                  | 95.045                     | .23391                    | -0.8417                  | 73.312                    | 72.470                  | -.002011                 | .17435                  | -44         |
| -42         | 8.8316                  | 11.9399*  | .010543                  | 4.0691                  | 94.854                     | .24576                    | -0.4211                  | 73.112                    | 72.691                  | -.001003                 | .17403                  | -42         |
| -40         | 9.3076                  | 10.9709*  | 0.010564                 | 3.8750                  | 94.661                     | 0.25806                   | 0.0000                   | 72.913                    | 72.913                  | 0.000000                 | 0.17373                 | -40         |
| -38         | 9.8035                  | 9.9611*   | .010586                  | 3.6922                  | 94.469                     | .27084                    | 0.4215                   | 72.712                    | 73.134                  | .001000                  | .17343                  | -38         |
| -36         | 10.320                  | 8.909*    | .010607                  | 3.5198                  | 94.275                     | .28411                    | 0.8434                   | 72.511                    | 73.354                  | .001995                  | .17313                  | -36         |
| -34         | 10.858                  | 7.814*    | .010629                  | 3.3571                  | 94.081                     | .29788                    | 1.2659                   | 72.309                    | 73.575                  | .002988                  | .17285                  | -34         |
| -32         | 11.417                  | 6.675*    | .010651                  | 3.2035                  | 93.886                     | .31216                    | 1.6887                   | 72.106                    | 73.795                  | .003976                  | .17257                  | -32         |
| -30         | 11.999                  | 5.490*    | 0.010674                 | 3.0585                  | 93.690                     | 0.32696                   | 2.1120                   | 71.903                    | 74.015                  | 0.004961                 | 0.17229                 | -30         |
| -28         | 12.604                  | 4.259*    | .010696                  | 2.9214                  | 93.493                     | .34231                    | 2.5358                   | 71.698                    | 74.234                  | .005942                  | .17203                  | -28         |
| -26         | 13.233                  | 2.979*    | .010719                  | 2.7917                  | 93.296                     | .35820                    | 2.9601                   | 71.494                    | 74.454                  | .006919                  | .17177                  | -26         |
| -24         | 13.886                  | 1.649*    | .010741                  | 2.6691                  | 93.098                     | .37466                    | 3.3848                   | 71.288                    | 74.673                  | .007894                  | .17151                  | -24         |
| -22         | 14.564                  | 0.270*    | .010764                  | 2.5529                  | 92.899                     | .39171                    | 3.8100                   | 71.081                    | 74.891                  | .008864                  | .17126                  | -22         |
| -20         | 15.267                  | 0.571     | 0.010788                 | 2.4429                  | 92.699                     | 0.40934                   | 4.2357                   | 70.874                    | 75.110                  | 0.009831                 | 0.17102                 | -20         |
| -18         | 15.996                  | 1.300     | .010811                  | 2.3387                  | 92.499                     | .42758                    | 4.6618                   | 70.666                    | 75.328                  | .010795                  | .17078                  | -18         |
| -16         | 16.753                  | 2.057     | .010834                  | 2.2399                  | 92.298                     | .44645                    | 5.0885                   | 70.456                    | 75.545                  | .011755                  | .17055                  | -16         |
| -14         | 17.536                  | 2.840     | .010858                  | 2.1461                  | 92.096                     | .46595                    | 5.5157                   | 70.246                    | 75.762                  | .012712                  | .17032                  | -14         |
| -12         | 18.348                  | 3.652     | .010882                  | 2.0572                  | 91.893                     | .48611                    | 5.9434                   | 70.036                    | 75.979                  | .013666                  | .17010                  | -12         |
| -10         | 19.189                  | 4.493     | 0.010906                 | 1.9727                  | 91.689                     | 0.50693                   | 6.3716                   | 69.824                    | 76.196                  | 0.014617                 | 0.16989                 | -10         |
| -8          | 20.059                  | 5.363     | .010931                  | 1.8924                  | 91.485                     | .52843                    | 6.8003                   | 69.611                    | 76.411                  | .015564                  | .16967                  | -8          |
| -6          | 20.960                  | 6.264     | .010955                  | 1.8161                  | 91.280                     | .55063                    | 7.2296                   | 69.397                    | 76.627                  | .016508                  | .16947                  | -6          |
| -4          | 21.891                  | 7.195     | .010980                  | 1.7436                  | 91.074                     | .57354                    | 7.6594                   | 69.183                    | 76.842                  | .017449                  | .16927                  | -4          |
| -2          | 22.854                  | 8.158     | .011005                  | 1.6745                  | 90.867                     | .59718                    | 8.0898                   | 68.967                    | 77.057                  | .018388                  | .16907                  | -2          |
| 0           | 23.849                  | 9.153     | 0.011030                 | 1.6089                  | 90.659                     | 0.62156                   | 8.5207                   | 68.750                    | 77.271                  | 0.019323                 | 0.16888                 | 0           |
| 2           | 24.878                  | 10.182    | .011056                  | 1.5463                  | 90.450                     | .64670                    | 8.9522                   | 68.533                    | 77.485                  | .020255                  | .16869                  | 2           |
| 4           | 25.939                  | 11.243    | .011082                  | 1.4867                  | 90.240                     | .67263                    | 9.3843                   | 68.314                    | 77.698                  | .021184                  | .16851                  | 4           |
| 6           | 27.036                  | 12.340    | .011107                  | 1.4299                  | 90.030                     | .69934                    | 9.8169                   | 68.094                    | 77.911                  | .022110                  | .16833                  | 6           |
| 8           | 28.167                  | 13.471    | .011134                  | 1.3758                  | 89.818                     | .72687                    | 10.250                   | 67.873                    | 78.123                  | .023033                  | .16815                  | 8           |
| 10          | 29.335                  | 14.639    | 0.011160                 | 1.3241                  | 89.606                     | 0.75523                   | 10.684                   | 67.651                    | 78.335                  | 0.023954                 | 0.16798                 | 10          |
| 12          | 30.539                  | 15.843    | .011187                  | 1.2748                  | 89.392                     | .78443                    | 11.118                   | 67.428                    | 78.546                  | .024871                  | .16782                  | 12          |
| 14          | 31.780                  | 17.084    | .011214                  | 1.2278                  | 89.178                     | .81449                    | 11.554                   | 67.203                    | 78.757                  | .025786                  | .16765                  | 14          |
| 16          | 33.060                  | 18.364    | .011241                  | 1.1828                  | 88.962                     | .84544                    | 11.989                   | 66.977                    | 78.966                  | .026699                  | .16750                  | 16          |
| 18          | 34.378                  | 19.682    | .011268                  | 1.1399                  | 88.746                     | .87729                    | 12.426                   | 66.750                    | 79.176                  | .027608                  | .16734                  | 18          |
| 20          | 35.736                  | 21.040    | 0.011296                 | 1.0988                  | 88.529                     | 0.91006                   | 12.863                   | 66.522                    | 79.385                  | 0.028515                 | 0.16719                 | 20          |
| 22          | 37.135                  | 22.439    | .011324                  | 1.0596                  | 88.310                     | .94377                    | 13.300                   | 66.293                    | 79.593                  | .029420                  | .16704                  | 22          |
| 24          | 38.574                  | 23.878    | .011352                  | 1.0220                  | 88.091                     | .97843                    | 13.739                   | 66.061                    | 79.800                  | .030322                  | .16690                  | 24          |
| 26          | 40.056                  | 25.360    | .011380                  | 0.98612                 | 87.870                     | 1.0141                    | 14.178                   | 65.829                    | 80.007                  | .031221                  | .16676                  | 26          |
| 28          | 41.580                  | 26.884    | .011409                  | 0.95173                 | 87.649                     | 1.0507                    | 14.618                   | 65.596                    | 80.214                  | .032118                  | .16662                  | 28          |

\*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours &amp; Co.



TABLE 2-PROPERTIES OF REFRIGERANT 12, LIQUID AND SATURATED VAPOR (Contd)

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>p | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| 30          | 43.148                  | 28.452    | 0.011438                 | 0.91880                 | 87.426                     | 1.0884                    | 15.058                   | 65.361                    | 80.419                  | 0.033013                 | 0.16648                 | 30          |
| 32          | 44.760                  | 30.064    | .011468                  | .88725                  | 87.202                     | 1.1271                    | 15.500                   | 65.124                    | 80.624                  | .033905                  | .16635                  | 32          |
| 34          | 46.417                  | 31.721    | .011497                  | .85702                  | 86.977                     | 1.1668                    | 15.942                   | 64.886                    | 80.828                  | .034796                  | .16622                  | 34          |
| 36          | 48.120                  | 33.424    | .011527                  | .82803                  | 86.751                     | 1.2077                    | 16.384                   | 64.647                    | 81.031                  | .035683                  | .16610                  | 36          |
| 38          | 49.870                  | 35.174    | .011557                  | .80023                  | 86.524                     | 1.2496                    | 16.828                   | 64.406                    | 81.234                  | .036569                  | .16598                  | 38          |
| 40          | 51.667                  | 36.971    | 0.011588                 | 0.77357                 | 86.296                     | 1.2927                    | 17.273                   | 64.163                    | 81.436                  | 0.037453                 | 0.16586                 | 40          |
| 42          | 53.513                  | 38.817    | .011619                  | .74798                  | 86.066                     | 1.3369                    | 17.718                   | 63.919                    | 81.637                  | .038334                  | .16574                  | 42          |
| 44          | 55.407                  | 40.711    | .011650                  | .72341                  | 85.836                     | 1.3823                    | 18.164                   | 63.673                    | 81.837                  | .039213                  | .16562                  | 44          |
| 46          | 57.352                  | 42.656    | .011682                  | .69982                  | 85.604                     | 1.4289                    | 18.611                   | 63.426                    | 82.037                  | .040091                  | .16551                  | 46          |
| 48          | 59.347                  | 44.651    | .011714                  | .67715                  | 85.371                     | 1.4768                    | 19.059                   | 63.177                    | 82.236                  | .040966                  | .16540                  | 48          |
| 50          | 61.394                  | 46.698    | 0.011746                 | 0.65537                 | 85.136                     | 1.5258                    | 19.507                   | 62.926                    | 82.433                  | 0.041839                 | 0.16530                 | 50          |
| 52          | 63.494                  | 48.798    | .011779                  | .63444                  | 84.900                     | 1.5762                    | 19.957                   | 62.673                    | 82.630                  | .042711                  | .16519                  | 52          |
| 54          | 65.646                  | 50.950    | .011811                  | .61431                  | 84.663                     | 1.6278                    | 20.408                   | 62.418                    | 82.826                  | .043581                  | .16509                  | 54          |
| 56          | 67.853                  | 53.157    | .011845                  | .59495                  | 84.425                     | 1.6808                    | 20.859                   | 62.162                    | 83.021                  | .044449                  | .16499                  | 56          |
| 58          | 70.115                  | 55.419    | .011879                  | .57632                  | 84.185                     | 1.7352                    | 21.312                   | 61.903                    | 83.215                  | .045316                  | .16489                  | 58          |
| 60          | 72.433                  | 57.737    | 0.011913                 | 0.55839                 | 83.944                     | 1.7909                    | 21.766                   | 61.643                    | 83.409                  | 0.046180                 | 0.16479                 | 60          |
| 62          | 74.807                  | 60.111    | .011947                  | .54112                  | 83.701                     | 1.8480                    | 22.221                   | 61.380                    | 83.601                  | .047044                  | .16470                  | 62          |
| 64          | 77.239                  | 62.543    | 0.011982                 | .52450                  | 83.457                     | 1.9066                    | 22.676                   | 61.116                    | 83.792                  | .047905                  | .16460                  | 64          |
| 66          | 79.729                  | 65.033    | .012017                  | .50848                  | 83.212                     | 1.9666                    | 23.133                   | 60.849                    | 83.982                  | .048765                  | .16451                  | 66          |
| 68          | 82.279                  | 67.583    | .012053                  | .49305                  | 82.965                     | 2.0282                    | 23.591                   | 60.580                    | 84.171                  | .049624                  | .16442                  | 68          |
| 70          | 84.888                  | 70.192    | 0.012089                 | 0.47818                 | 82.717                     | 2.0913                    | 24.050                   | 60.309                    | 84.359                  | 0.050482                 | 0.16434                 | 70          |
| 72          | 87.559                  | 72.863    | .012126                  | .46383                  | 82.467                     | 2.1559                    | 24.511                   | 60.035                    | 84.546                  | .051338                  | .16425                  | 72          |
| 74          | 90.292                  | 75.596    | .012163                  | .45000                  | 82.215                     | 2.2222                    | 24.973                   | 59.759                    | 84.732                  | .052193                  | .16417                  | 74          |
| 76          | 93.087                  | 78.391    | .012201                  | .43666                  | 81.962                     | 2.2901                    | 25.435                   | 59.481                    | 84.916                  | .053047                  | .16408                  | 76          |
| 78          | 95.946                  | 81.250    | .012239                  | .42378                  | 81.707                     | 2.3597                    | 25.899                   | 59.201                    | 85.100                  | .053900                  | .16400                  | 78          |
| 80          | 98.870                  | 84.174    | 0.012277                 | 0.41135                 | 81.450                     | 2.4310                    | 26.365                   | 58.917                    | 85.282                  | 0.054751                 | 0.16392                 | 80          |
| 82          | 101.86                  | 87.16     | .012316                  | .39935                  | 81.192                     | 2.5041                    | 26.832                   | 58.631                    | 85.463                  | .055602                  | .16384                  | 82          |
| 84          | 104.92                  | 90.22     | .012356                  | .38776                  | 80.932                     | 2.5789                    | 27.300                   | 58.343                    | 85.643                  | .056452                  | .16376                  | 84          |
| 86          | 108.04                  | 93.34     | 0.012396                 | .37657                  | 80.671                     | 2.6556                    | 27.769                   | 58.052                    | 85.821                  | .057301                  | .16368                  | 86          |
| 88          | 111.23                  | 96.53     | 0.012437                 | .36575                  | 80.407                     | 2.7341                    | 28.241                   | 57.757                    | 85.998                  | .058149                  | .16360                  | 88          |
| 90          | 114.49                  | 99.79     | 0.012478                 | 0.35529                 | 80.142                     | 2.8146                    | 28.713                   | 57.461                    | 86.174                  | 0.058997                 | 0.16353                 | 90          |
| 92          | 117.82                  | 103.12    | .012520                  | .34518                  | 79.874                     | 2.8970                    | 29.187                   | 57.161                    | 86.348                  | .059844                  | .16345                  | 92          |
| 94          | 121.22                  | 106.52    | .012562                  | .33540                  | 79.605                     | 2.9815                    | 29.663                   | 56.858                    | 86.521                  | .060690                  | .16338                  | 94          |
| 96          | 124.70                  | 110.00    | .012605                  | .32594                  | 79.334                     | 3.0680                    | 30.140                   | 56.551                    | 86.691                  | .061536                  | .16330                  | 96          |
| 98          | 128.24                  | 113.54    | .012649                  | .31679                  | 79.061                     | 3.1566                    | 30.619                   | 56.242                    | 86.861                  | .062381                  | .16323                  | 98          |
| 100         | 131.86                  | 117.16    | 0.012693                 | 0.30794                 | 78.785                     | 3.2474                    | 31.100                   | 55.929                    | 87.029                  | 0.063227                 | 0.16315                 | 100         |
| 102         | 135.56                  | 120.86    | .012738                  | .29937                  | 78.508                     | 3.3404                    | 31.583                   | 55.613                    | 87.196                  | .064072                  | .16308                  | 102         |
| 104         | 139.33                  | 124.63    | .012783                  | .29106                  | 78.228                     | 3.4357                    | 32.067                   | 55.293                    | 87.360                  | .064916                  | .16301                  | 104         |
| 106         | 143.18                  | 128.48    | .012829                  | .28303                  | 77.946                     | 3.5333                    | 32.553                   | 54.970                    | 87.523                  | .065761                  | .16293                  | 106         |
| 108         | 147.11                  | 132.41    | .012876                  | .27524                  | 77.662                     | 3.6332                    | 33.041                   | 54.643                    | 87.684                  | .066606                  | .16286                  | 108         |
| 110         | 151.11                  | 136.41    | 0.012924                 | 0.26769                 | 77.376                     | 3.7357                    | 33.531                   | 54.313                    | 87.844                  | 0.067451                 | 0.16279                 | 110         |
| 112         | 155.19                  | 140.49    | .012972                  | .26037                  | 77.087                     | 3.8406                    | 34.023                   | 53.978                    | 88.001                  | .068296                  | .16271                  | 112         |
| 114         | 159.36                  | 144.66    | .013022                  | .25328                  | 76.795                     | 3.9482                    | 34.517                   | 53.639                    | 88.156                  | .069141                  | .16264                  | 114         |
| 116         | 163.61                  | 148.91    | .013072                  | .24641                  | 76.501                     | 4.0584                    | 35.014                   | 53.296                    | 88.310                  | .069987                  | .16256                  | 116         |
| 118         | 167.94                  | 153.24    | .013123                  | .23974                  | 76.205                     | 4.1713                    | 35.512                   | 52.949                    | 88.461                  | .070833                  | .16249                  | 118         |
| 120         | 172.35                  | 157.65    | 0.013174                 | 0.23326                 | 75.906                     | 4.2870                    | 36.013                   | 52.597                    | 88.610                  | 0.071680                 | 0.16241                 | 120         |
| 122         | 176.85                  | 162.15    | .013227                  | .22698                  | 75.604                     | 4.4056                    | 36.516                   | 52.241                    | 88.757                  | .072528                  | .16234                  | 122         |
| 124         | 181.43                  | 166.73    | .013280                  | .22089                  | 75.299                     | 4.5272                    | 37.021                   | 51.881                    | 88.902                  | .073376                  | .16226                  | 124         |
| 126         | 186.10                  | 171.40    | .013335                  | .21497                  | 74.991                     | 4.6518                    | 37.529                   | 51.515                    | 89.044                  | .074225                  | .16218                  | 126         |
| 128         | 190.86                  | 176.16    | .013390                  | .20922                  | 74.680                     | 4.7796                    | 38.040                   | 51.144                    | 89.184                  | .075075                  | .16210                  | 128         |
| 130         | 195.71                  | 181.01    | 0.013447                 | 0.20364                 | 74.367                     | 4.9107                    | 38.553                   | 50.768                    | 89.321                  | 0.075927                 | 0.16202                 | 130         |
| 132         | 200.64                  | 185.94    | .013504                  | .19821                  | 74.050                     | 5.0451                    | 39.069                   | 50.387                    | 89.456                  | .076779                  | .16194                  | 132         |
| 134         | 205.67                  | 190.97    | .013563                  | .19294                  | 73.729                     | 5.1829                    | 39.588                   | 50.000                    | 89.588                  | .077623                  | .16185                  | 134         |
| 136         | 210.79                  | 196.09    | .013623                  | .18782                  | 73.406                     | 5.3244                    | 40.110                   | 49.608                    | 89.718                  | .078489                  | .16177                  | 136         |
| 138         | 216.01                  | 201.31    | .013684                  | .18283                  | 73.079                     | 5.4695                    | 40.634                   | 49.210                    | 89.844                  | .079346                  | .16168                  | 138         |
| 140         | 221.32                  | 206.62    | 0.013746                 | 0.17799                 | 72.748                     | 5.6184                    | 41.162                   | 48.805                    | 89.967                  | 0.080205                 | 0.16159                 | 140         |
| 142         | 226.72                  | 212.02    | .013810                  | .17327                  | 72.413                     | 5.7713                    | 41.693                   | 48.394                    | 90.087                  | .081065                  | .16150                  | 142         |
| 144         | 232.22                  | 217.52    | .013874                  | .16868                  | 72.075                     | 5.9283                    | 42.227                   | 47.977                    | 90.204                  | .081928                  | .16140                  | 144         |
| 146         | 237.82                  | 223.12    | .013941                  | .16422                  | 71.732                     | 6.0895                    | 42.765                   | 47.553                    | 90.318                  | .082794                  | .16130                  | 146         |
| 148         | 243.51                  | 228.81    | .014008                  | .15987                  | 71.386                     | 6.2551                    | 43.306                   | 47.122                    | 90.428                  | .083661                  | .16120                  | 148         |
| 150         | 249.31                  | 234.61    | 0.014078                 | 0.15564                 | 71.035                     | 6.4252                    | 43.850                   | 46.684                    | 90.534                  | 0.084531                 | 0.16110                 | 150         |
| 152         | 255.20                  | 240.50    | .014148                  | .15151                  | 70.679                     | 6.6001                    | 44.399                   | 46.238                    | 90.637                  | .085404                  | .16099                  | 152         |
| 154         | 261.20                  | 246.50    | .014221                  | .14750                  | 70.319                     | 6.7799                    | 44.951                   | 45.784                    | 90.735                  | .086280                  | .16088                  | 154         |
| 156         | 267.30                  | 252.60    | .014295                  | .14358                  | 69.954                     | 6.9648                    | 45.508                   | 45.322                    | 90.830                  | .087159                  | .16077                  | 156         |
| 158         | 273.51                  | 258.81    | .014371                  | .13976                  | 69.584                     | 7.1551                    | 46.068                   | 44.852                    | 90.920                  | .088041                  | .16065                  | 158         |
| 160         | 279.82                  | 265.12    | 0.014449                 | 0.13604                 | 69.209                     | 7.3509                    | 46.633                   | 44.373                    | 91.006                  | 0.088927                 | 0.16053                 | 160         |



TABLE 3-PROPERTIES OF REFRIGERANT 500, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>p | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| -40         | 10.84                   | 7.86*     | 0.0119                   | 4.0757                  | 84.37                      | 0.2454                    | 0.00                     | 89.91                     | 89.91                   | 0.00000                  | 0.21421                 | -40         |
| -38         | 11.42                   | 6.68*     | .0119                    | 3.8829                  | 84.19                      | .2575                     | 0.51                     | 89.68                     | 90.19                   | .00122                   | .21387                  | -38         |
| -36         | 12.03                   | 5.44*     | .0119                    | 3.6992                  | 84.00                      | .2703                     | 1.02                     | 89.45                     | 90.47                   | .00243                   | .21352                  | -36         |
| -34         | 12.66                   | 4.15*     | .0119                    | 3.5276                  | 83.82                      | .2835                     | 1.54                     | 89.21                     | 90.75                   | .00365                   | .21318                  | -34         |
| -32         | 13.31                   | 2.83*     | .0120                    | 3.3671                  | 83.63                      | .2970                     | 2.05                     | 88.97                     | 91.02                   | .00485                   | .21286                  | -32         |
| -30         | 14.00                   | 1.40*     | 0.0120                   | 3.2121                  | 83.45                      | 0.3113                    | 2.57                     | 88.73                     | 91.30                   | 0.00606                  | 0.21252                 | -30         |
| -28         | 14.71                   | 0.01      | .0120                    | 3.0674                  | 83.26                      | .3260                     | 3.09                     | 88.49                     | 91.58                   | .00725                   | .21221                  | -28         |
| -26         | 15.45                   | 0.75      | .0120                    | 2.9302                  | 83.07                      | .3413                     | 3.60                     | 88.25                     | 91.85                   | .00845                   | .21189                  | -26         |
| -24         | 16.21                   | 1.51      | .0121                    | 2.8020                  | 82.89                      | .3569                     | 4.13                     | 88.00                     | 92.13                   | .00963                   | .21160                  | -24         |
| -22         | 17.01                   | 2.31      | .0121                    | 2.6788                  | 82.70                      | .3733                     | 4.65                     | 87.75                     | 92.40                   | .01083                   | .21130                  | -22         |
| -20         | 17.84                   | 3.14      | 0.0121                   | 2.5622                  | 82.51                      | 0.3903                    | 5.17                     | 87.50                     | 92.67                   | 0.01202                  | 0.21101                 | -20         |
| -18         | 18.70                   | 4.00      | .0121                    | 2.4520                  | 82.32                      | .4078                     | 5.70                     | 87.25                     | 92.95                   | .01322                   | .21072                  | -18         |
| -16         | 19.59                   | 4.89      | .0122                    | 2.3477                  | 82.13                      | .4260                     | 6.22                     | 87.00                     | 93.22                   | .01438                   | .21044                  | -16         |
| -14         | 20.51                   | 5.81      | .0122                    | 2.2491                  | 81.94                      | .4446                     | 6.75                     | 86.74                     | 93.49                   | .01557                   | .21017                  | -14         |
| -12         | 21.47                   | 6.77      | .0122                    | 2.1548                  | 81.75                      | .4641                     | 7.27                     | 86.49                     | 93.76                   | .01674                   | .20991                  | -12         |
| -10         | 22.46                   | 7.76      | 0.0123                   | 2.0657                  | 81.56                      | 0.4841                    | 7.80                     | 86.23                     | 94.03                   | 0.01793                  | 0.20965                 | -10         |
| -8          | 23.49                   | 8.79      | .0123                    | 1.9807                  | 81.37                      | .5049                     | 8.33                     | 85.97                     | 94.30                   | .01909                   | .20939                  | -8          |
| -6          | 24.55                   | 9.85      | .0123                    | 1.9004                  | 81.17                      | .5262                     | 8.87                     | 85.70                     | 94.57                   | .02027                   | .20914                  | -6          |
| -4          | 25.65                   | 10.95     | .0123                    | 1.8238                  | 80.98                      | .5483                     | 9.40                     | 85.44                     | 94.84                   | .02144                   | .20890                  | -4          |
| -2          | 26.79                   | 12.09     | .0124                    | 1.7507                  | 80.78                      | .5712                     | 9.94                     | 85.17                     | 95.11                   | .02259                   | .20866                  | -2          |
| 0           | 27.96                   | 13.26     | 0.0124                   | 1.6818                  | 80.59                      | 0.5946                    | 10.47                    | 84.90                     | 95.37                   | 0.02376                  | 0.20843                 | 0           |
| 2           | 29.18                   | 14.48     | .0124                    | 1.6155                  | 80.39                      | .6190                     | 11.01                    | 84.63                     | 95.64                   | .02491                   | .20819                  | 2           |
| 4           | 30.43                   | 15.73     | .0125                    | 1.5530                  | 80.20                      | .6439                     | 11.55                    | 84.35                     | 95.90                   | .02608                   | .20797                  | 4           |
| 6           | 31.73                   | 17.03     | .0125                    | 1.4929                  | 80.00                      | .6698                     | 12.09                    | 84.08                     | 96.17                   | .02722                   | .20775                  | 6           |
| 8           | 33.06                   | 18.36     | .0125                    | 1.4362                  | 79.80                      | .6963                     | 12.63                    | 83.80                     | 96.43                   | .02839                   | .20754                  | 8           |
| 10          | 34.45                   | 19.75     | 0.0126                   | 1.3813                  | 79.60                      | 0.7239                    | 13.17                    | 83.52                     | 96.69                   | 0.02954                  | 0.20732                 | 10          |
| 12          | 35.88                   | 21.18     | .0126                    | 1.3292                  | 79.40                      | .7523                     | 13.71                    | 83.24                     | 96.95                   | .03067                   | .20711                  | 12          |
| 14          | 37.35                   | 22.65     | .0126                    | 1.2796                  | 79.20                      | .7815                     | 14.26                    | 82.95                     | 97.21                   | .03182                   | .20691                  | 14          |
| 16          | 38.86                   | 24.16     | .0127                    | 1.2325                  | 79.00                      | .8114                     | 14.81                    | 82.66                     | 97.47                   | .03296                   | .20672                  | 16          |
| 18          | 40.42                   | 25.72     | .0127                    | 1.1873                  | 78.80                      | .8422                     | 15.35                    | 82.37                     | 97.72                   | .03411                   | .20652                  | 18          |
| 20          | 42.03                   | 27.33     | 0.0127                   | 1.1440                  | 78.59                      | 0.8741                    | 15.91                    | 82.07                     | 97.98                   | 0.03526                  | 0.20633                 | 20          |
| 22          | 43.69                   | 28.99     | .0128                    | 1.1027                  | 78.39                      | 0.9069                    | 16.45                    | 81.78                     | 98.23                   | .03638                   | .20614                  | 22          |
| 24          | 45.40                   | 30.70     | .0128                    | 1.0631                  | 78.18                      | 0.9407                    | 17.01                    | 81.48                     | 98.49                   | .03752                   | .20595                  | 24          |
| 26          | 47.15                   | 32.45     | .0128                    | 1.0254                  | 77.98                      | 0.9752                    | 17.56                    | 81.18                     | 98.74                   | .03865                   | .20578                  | 26          |
| 28          | 48.96                   | 34.26     | .0129                    | 0.9892                  | 77.77                      | 1.0109                    | 18.12                    | 80.87                     | 98.99                   | .03978                   | .20560                  | 28          |
| 30          | 50.82                   | 36.12     | 0.0129                   | 0.9545                  | 77.56                      | 1.0476                    | 18.67                    | 80.57                     | 99.24                   | 0.04092                  | 0.20542                 | 30          |
| 32          | 52.74                   | 38.04     | .0129                    | .9212                   | 77.35                      | 1.0855                    | 19.22                    | 80.26                     | 99.48                   | .04203                   | .20525                  | 32          |
| 34          | 54.71                   | 40.01     | .0130                    | .8894                   | 77.14                      | 1.1244                    | 19.79                    | 79.94                     | 99.73                   | .04316                   | .20508                  | 34          |
| 36          | 56.72                   | 42.02     | .0130                    | .8591                   | 76.93                      | 1.1640                    | 20.34                    | 79.63                     | 99.97                   | .04430                   | .20491                  | 36          |
| 38          | 58.80                   | 44.10     | .0130                    | .8298                   | 76.72                      | 1.2051                    | 20.91                    | 79.31                     | 100.22                  | .04542                   | .20475                  | 38          |
| 40          | 60.94                   | 46.24     | 0.0131                   | 0.8017                  | 76.50                      | 1.2473                    | 21.47                    | 78.99                     | 100.46                  | 0.04654                  | 0.20458                 | 40          |
| 42          | 63.14                   | 48.44     | .0131                    | .7747                   | 76.29                      | 1.2908                    | 22.03                    | 78.67                     | 100.70                  | .04764                   | .20442                  | 42          |
| 44          | 65.39                   | 50.69     | .0131                    | .7490                   | 76.07                      | 1.3352                    | 22.60                    | 78.34                     | 100.94                  | .04875                   | .20426                  | 44          |
| 46          | 67.71                   | 53.01     | .0132                    | .7241                   | 75.86                      | 1.3811                    | 23.16                    | 78.01                     | 101.17                  | .04986                   | .20410                  | 46          |
| 48          | 70.09                   | 55.39     | .0132                    | .7002                   | 75.64                      | 1.4282                    | 23.75                    | 77.66                     | 101.41                  | .05099                   | .20395                  | 48          |
| 50          | 72.52                   | 57.82     | 0.0133                   | 0.6774                  | 75.42                      | 1.4763                    | 24.31                    | 77.33                     | 101.64                  | 0.05212                  | 0.20380                 | 50          |
| 52          | 75.02                   | 60.32     | .0133                    | .6554                   | 75.20                      | 1.5258                    | 24.88                    | 76.99                     | 101.87                  | .05321                   | .20365                  | 52          |
| 54          | 77.57                   | 62.87     | .0133                    | .6343                   | 74.97                      | 1.5764                    | 25.46                    | 76.64                     | 102.10                  | .05431                   | .20350                  | 54          |
| 56          | 80.22                   | 65.52     | .0134                    | .6138                   | 74.75                      | 1.6291                    | 26.04                    | 76.29                     | 102.33                  | .05543                   | .20335                  | 56          |
| 58          | 82.91                   | 68.21     | .0134                    | .5943                   | 74.52                      | 1.6826                    | 26.59                    | 75.96                     | 102.55                  | .05649                   | .20320                  | 58          |
| 60          | 85.66                   | 70.96     | 0.0135                   | 0.5756                  | 74.30                      | 1.7374                    | 27.19                    | 75.59                     | 102.78                  | 0.05763                  | 0.20306                 | 60          |
| 62          | 88.49                   | 73.79     | .0135                    | .5575                   | 74.07                      | 1.7939                    | 27.76                    | 75.24                     | 103.00                  | .05872                   | .20291                  | 62          |
| 64          | 91.39                   | 76.69     | .0135                    | .5400                   | 73.84                      | 1.8518                    | 28.33                    | 74.89                     | 103.22                  | .05979                   | .20277                  | 64          |
| 66          | 94.37                   | 79.67     | .0136                    | .5231                   | 73.61                      | 1.9116                    | 28.92                    | 74.51                     | 103.43                  | .06091                   | .20262                  | 66          |
| 68          | 97.41                   | 82.71     | .0136                    | .5069                   | 73.38                      | 1.9727                    | 29.52                    | 74.13                     | 103.65                  | .06203                   | .20248                  | 68          |
| 70          | 100.51                  | 85.81     | 0.0137                   | 0.4914                  | 73.14                      | 2.0350                    | 30.10                    | 73.76                     | 103.86                  | 0.06311                  | 0.20234                 | 70          |
| 72          | 103.71                  | 89.01     | .0137                    | .4763                   | 72.91                      | 2.0996                    | 30.68                    | 73.39                     | 104.07                  | .06419                   | .20220                  | 72          |
| 74          | 106.97                  | 92.27     | .0138                    | .4618                   | 72.67                      | 2.1655                    | 31.27                    | 73.01                     | 104.28                  | .06527                   | .20206                  | 74          |
| 76          | 110.29                  | 95.59     | .0138                    | .4479                   | 72.43                      | 2.2328                    | 31.87                    | 72.62                     | 104.49                  | .06637                   | .20192                  | 76          |
| 78          | 113.70                  | 99.00     | .0139                    | .4344                   | 72.19                      | 2.3021                    | 32.47                    | 72.22                     | 104.69                  | .06749                   | .20178                  | 78          |
| 80          | 117.20                  | 102.5     | 0.0139                   | 0.4213                  | 71.95                      | 2.3735                    | 33.06                    | 71.83                     | 104.89                  | 0.06855                  | 0.20164                 | 80          |
| 82          | 120.78                  | 106.1     | .0139                    | .4087                   | 71.70                      | 2.4469                    | 33.63                    | 71.46                     | 105.09                  | .06959                   | .20149                  | 82          |
| 84          | 124.40                  | 109.7     | .0140                    | .3967                   | 71.46                      | 2.5210                    | 34.24                    | 71.04                     | 105.28                  | .07071                   | .20136                  | 84          |
| 86          | 128.14                  | 113.4     | .0140                    | .3849                   | 71.21                      | 2.5981                    | 34.84                    | 70.63                     | 105.47                  | .07179                   | .20121                  | 86          |
| 88          | 131.96                  | 117.3     | .0141                    | .3735                   | 70.96                      | 2.6772                    | 35.44                    | 70.22                     | 105.66                  | .07288                   | .20107                  | 88          |

\*Inches of mercury below one atmosphere.

TABLE 3-PROPERTIES OF REFRIGERANT 500, LIQUID AND SATURATED VAPOR (Contd)

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>p | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| 90          | 135.86                  | 121.2     | 0.0141                   | 0.3626                  | 70.70                      | 2.7581                    | 36.04                    | 69.81                     | 105.85                  | 0.07395                  | 0.20092                 | 90          |
| 92          | 139.83                  | 125.1     | .0142                    | .3520                   | 70.45                      | 2.8409                    | 36.66                    | 69.37                     | 106.03                  | .07505                   | .20078                  | 92          |
| 94          | 143.90                  | 129.2     | .0142                    | .3418                   | 70.19                      | 2.9261                    | 37.26                    | 68.96                     | 106.22                  | .07611                   | .20064                  | 94          |
| 96          | 148.03                  | 133.3     | .0143                    | .3319                   | 69.93                      | 3.0128                    | 37.88                    | 68.51                     | 106.39                  | .07722                   | .20049                  | 96          |
| 98          | 152.27                  | 137.6     | .0144                    | .3223                   | 69.67                      | 3.1024                    | 38.47                    | 68.10                     | 106.57                  | .07826                   | .20035                  | 98          |
| 100         | 156.61                  | 141.9     | 0.0144                   | 0.3130                  | 69.41                      | 3.1947                    | 39.09                    | 67.65                     | 106.74                  | 0.07935                  | 0.20019                 | 100         |
| 102         | 161.02                  | 146.3     | .0145                    | .3041                   | 69.14                      | 3.2889                    | 39.71                    | 67.20                     | 106.91                  | .08042                   | .20004                  | 102         |
| 104         | 165.55                  | 150.9     | .0145                    | .2953                   | 68.87                      | 3.3860                    | 40.33                    | 66.74                     | 107.07                  | .08151                   | .19989                  | 104         |
| 106         | 170.14                  | 155.4     | .0146                    | .2869                   | 68.60                      | 3.4850                    | 40.96                    | 66.27                     | 107.23                  | .08261                   | .19974                  | 106         |
| 108         | 174.84                  | 160.1     | .0146                    | .2788                   | 68.33                      | 3.5871                    | 41.59                    | 65.80                     | 107.39                  | .08367                   | .19958                  | 108         |
| 110         | 179.62                  | 164.9     | 0.0147                   | 0.2709                  | 68.05                      | 3.6914                    | 42.22                    | 65.32                     | 107.54                  | 0.08479                  | 0.19942                 | 110         |
| 112         | 184.51                  | 169.8     | .0148                    | .2632                   | 67.78                      | 3.7990                    | 42.82                    | 64.87                     | 107.69                  | .08482                   | .19926                  | 112         |
| 114         | 189.47                  | 174.8     | .0148                    | .2558                   | 67.49                      | 3.9086                    | 43.47                    | 64.37                     | 107.84                  | .08691                   | .19910                  | 114         |
| 116         | 194.55                  | 179.9     | .0149                    | .2486                   | 67.21                      | 4.0218                    | 44.11                    | 63.87                     | 107.98                  | .08800                   | .19893                  | 116         |
| 118         | 199.71                  | 185.0     | .0149                    | .2417                   | 66.92                      | 4.1376                    | 44.72                    | 63.40                     | 108.12                  | .08905                   | .19876                  | 118         |
| 120         | 204.99                  | 190.3     | 0.0150                   | 0.2349                  | 66.63                      | 4.2566                    | 45.35                    | 62.90                     | 108.25                  | 0.09012                  | 0.19859                 | 120         |
| 122         | 210.40                  | 195.7     | .0151                    | .2283                   | 66.34                      | 4.3807                    | 46.02                    | 62.35                     | 108.37                  | .09124                   | .19841                  | 122         |
| 124         | 215.88                  | 201.2     | .0151                    | .2219                   | 66.04                      | 4.5068                    | 46.69                    | 61.81                     | 108.50                  | .09236                   | .19823                  | 124         |
| 126         | 221.44                  | 206.7     | .0152                    | .2157                   | 65.74                      | 4.6357                    | 47.33                    | 61.29                     | 108.62                  | .09342                   | .19805                  | 126         |
| 128         | 227.13                  | 212.4     | .0153                    | .2097                   | 65.43                      | 4.7690                    | 47.98                    | 60.75                     | 108.73                  | .09451                   | .19786                  | 128         |
| 130         | 232.89                  | 218.2     | 0.0154                   | 0.2039                  | 65.13                      | 4.9050                    | 48.65                    | 60.19                     | 108.84                  | 0.09560                  | 0.19767                 | 130         |
| 132         | 238.80                  | 224.1     | .0154                    | .1982                   | 64.81                      | 5.0463                    | 49.28                    | 59.66                     | 108.94                  | .09666                   | .19747                  | 132         |
| 134         | 244.84                  | 230.1     | .0155                    | .1926                   | 64.49                      | 5.1924                    | 49.91                    | 59.13                     | 109.04                  | .09771                   | .19726                  | 134         |
| 136         | 250.96                  | 236.3     | .0156                    | .1872                   | 64.17                      | 5.3420                    | 50.59                    | 58.54                     | 109.13                  | .09883                   | .19705                  | 136         |
| 138         | 257.17                  | 242.5     | .0157                    | .1820                   | 63.85                      | 5.4951                    | 51.30                    | 57.91                     | 109.21                  | .09996                   | .19684                  | 138         |
| 140         | 263.52                  | 248.8     | 0.0157                   | 0.1769                  | 63.52                      | 5.6528                    | 52.02                    | 57.27                     | 109.29                  | 0.10114                  | 0.19663                 | 140         |
| 142         | 269.99                  | 255.3     | .0158                    | .1719                   | 63.18                      | 5.8170                    | 52.73                    | 56.63                     | 109.36                  | .10228                   | .19639                  | 142         |
| 144         | 276.55                  | 261.9     | .0159                    | .1670                   | 62.84                      | 5.9878                    | 53.45                    | 55.97                     | 109.42                  | .10344                   | .19615                  | 144         |
| 146         | 283.24                  | 268.5     | .0160                    | .1623                   | 62.49                      | 6.1626                    | 54.15                    | 55.33                     | 109.48                  | .10456                   | .19591                  | 146         |
| 148         | 290.04                  | 275.3     | .0161                    | .1577                   | 62.14                      | 6.3431                    | 54.86                    | 54.67                     | 109.53                  | .10569                   | .19565                  | 148         |
| 150         | 296.97                  | 282.3     | 0.0162                   | 0.1531                  | 61.78                      | 6.5304                    | 55.62                    | 53.95                     | 109.57                  | 0.10691                  | 0.19539                 | 150         |
| 152         | 304.01                  | 289.3     | .0163                    | .1487                   | 61.42                      | 6.7241                    | 56.34                    | 53.25                     | 109.59                  | .10806                   | .19511                  | 152         |
| 154         | 311.18                  | 296.5     | .0164                    | .1444                   | 61.05                      | 6.9253                    | 57.07                    | 52.54                     | 109.61                  | .10922                   | .19483                  | 154         |
| 156         | 318.47                  | 303.8     | .0165                    | .1402                   | 60.66                      | 7.1342                    | 57.82                    | 51.80                     | 109.62                  | .11040                   | .19453                  | 156         |
| 158         | 325.87                  | 311.2     | .0166                    | .1360                   | 60.28                      | 7.3510                    | 58.61                    | 51.01                     | 109.62                  | .11163                   | .19421                  | 158         |
| 160         | 333.40                  | 318.7     | 0.0167                   | 0.1320                  | 59.88                      | 7.5772                    | 59.35                    | 50.25                     | 109.60                  | 0.11280                  | 0.19389                 | 160         |



TABLE 4-PROPERTIES OF REFRIGERANT 22, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| -155        | 0.2088                  | 29.50*    | 0.01014                  | 180.8                   | 98.67                      | 0.005531                  | -27.10                   | 114.04                    | 86.95                   | -0.07512                 | 0.2292                  | -155        |
| -150        | 0.2716                  | 29.37*    | .01018                   | 141.2                   | 98.24                      | 0.007081                  | -25.97                   | 113.50                    | 87.52                   | -.07147                  | .2950                   | -150        |
| -145        | 0.3500                  | 29.21*    | .01023                   | 111.3                   | 97.80                      | 0.008982                  | -24.85                   | 112.95                    | 88.10                   | -.06787                  | .2911                   | -145        |
| -140        | 0.4470                  | 29.01*    | .01027                   | 88.53                   | 97.36                      | 0.01130                   | -23.73                   | 112.41                    | 88.68                   | -.06432                  | .2873                   | -140        |
| -135        | 0.5658                  | 28.77*    | .01032                   | 70.98                   | 96.92                      | 0.01409                   | -22.60                   | 111.86                    | 89.26                   | -.06082                  | .2837                   | -135        |
| -130        | 0.7106                  | 28.47*    | 0.01037                  | 57.36                   | 96.48                      | 0.01744                   | -21.46                   | 111.31                    | 89.85                   | -0.05736                 | 0.2803                  | -130        |
| -125        | 0.8855                  | 28.19*    | .01041                   | 46.69                   | 96.04                      | 0.02142                   | -20.33                   | 110.76                    | 90.43                   | -.05394                  | .2770                   | -125        |
| -120        | 1.095                   | 27.69*    | .01046                   | 38.28                   | 95.59                      | 0.02612                   | -19.19                   | 110.21                    | 91.02                   | -.05055                  | .2739                   | -120        |
| -115        | 1.346                   | 27.18*    | .01051                   | 31.59                   | 95.14                      | 0.03165                   | -18.04                   | 109.65                    | 91.61                   | -.04720                  | .2709                   | -115        |
| -110        | 1.642                   | 26.58*    | .01056                   | 26.24                   | 94.68                      | 0.03811                   | -16.89                   | 109.08                    | 92.20                   | -.04389                  | .2681                   | -110        |
| -105        | 1.990                   | 25.87*    | 0.01061                  | 21.93                   | 94.23                      | 0.04560                   | -15.73                   | 108.51                    | 92.78                   | -0.04060                 | 0.2653                  | -105        |
| -100        | 2.398                   | 25.04*    | .01066                   | 18.43                   | 93.77                      | 0.05425                   | -14.56                   | 107.94                    | 93.37                   | -.03734                  | .2627                   | -100        |
| -95         | 2.873                   | 24.07*    | .01072                   | 15.58                   | 93.31                      | 0.06419                   | -13.39                   | 107.35                    | 93.96                   | -.03411                  | .2603                   | -95         |
| -90         | 3.423                   | 22.95*    | .01077                   | 13.24                   | 92.84                      | 0.07556                   | -12.22                   | 106.76                    | 94.54                   | -.03091                  | .2579                   | -90         |
| -85         | 4.056                   | 21.66*    | .01083                   | 11.30                   | 92.38                      | 0.08849                   | -11.03                   | 106.16                    | 95.13                   | -.02773                  | .2556                   | -85         |
| -80         | 4.782                   | 20.19*    | 0.01088                  | 9.695                   | 91.91                      | 0.1032                    | -9.838                   | 105.55                    | 95.71                   | -0.02457                 | 0.2534                  | -80         |
| -78         | 5.101                   | 19.54*    | .01090                   | 9.130                   | 91.72                      | 0.1095                    | -9.359                   | 105.30                    | 95.94                   | -.02331                  | .2526                   | -78         |
| -76         | 5.436                   | 18.85*    | .01093                   | 8.604                   | 91.53                      | 0.1162                    | -8.878                   | 105.05                    | 96.18                   | -.02206                  | .2517                   | -76         |
| -74         | 5.790                   | 18.13*    | .01095                   | 8.115                   | 91.34                      | 0.1232                    | -8.397                   | 104.80                    | 96.41                   | -.02081                  | .2509                   | -74         |
| -72         | 6.161                   | 17.38*    | .01097                   | 7.658                   | 91.14                      | 0.1306                    | -7.914                   | 104.55                    | 96.64                   | -.01956                  | .2501                   | -72         |
| -70         | 6.552                   | 16.58*    | 0.01096                  | 7.232                   | 90.95                      | 0.1383                    | -7.429                   | 104.30                    | 96.87                   | -0.01832                 | 0.2493                  | -70         |
| -68         | 6.962                   | 15.75*    | .01102                   | 6.834                   | 90.76                      | 0.1463                    | -6.944                   | 104.04                    | 97.10                   | -.01708                  | .2486                   | -68         |
| -66         | 7.393                   | 14.87*    | .01104                   | 6.463                   | 90.57                      | 0.1548                    | -6.457                   | 103.79                    | 97.33                   | -.01584                  | .2478                   | -66         |
| -64         | 7.846                   | 13.95*    | .01107                   | 6.114                   | 90.37                      | 0.1636                    | -5.968                   | 103.53                    | 97.56                   | -.01460                  | .2470                   | -64         |
| -62         | 8.321                   | 12.98*    | .01109                   | 5.789                   | 90.18                      | 0.1727                    | -5.479                   | 103.26                    | 97.79                   | -.01337                  | .2463                   | -62         |
| -60         | 8.818                   | 11.97*    | 0.01113                  | 5.484                   | 89.99                      | 0.1823                    | -4.987                   | 103.00                    | 98.01                   | -0.01214                 | 0.2456                  | -60         |
| -58         | 9.339                   | 10.91*    | .01114                   | 5.199                   | 89.79                      | 0.1924                    | -4.495                   | 102.74                    | 98.24                   | -.01092                  | .2448                   | -58         |
| -56         | 9.884                   | 9.798*    | .01116                   | 4.931                   | 89.60                      | 0.2028                    | -4.001                   | 102.47                    | 98.47                   | -.00969                  | .2441                   | -56         |
| -54         | 10.45                   | 8.636*    | .01119                   | 4.680                   | 89.40                      | 0.2137                    | -3.506                   | 102.20                    | 98.69                   | -.00847                  | .2435                   | -54         |
| -52         | 11.05                   | 7.422*    | .01121                   | 4.444                   | 89.20                      | 0.2250                    | -3.009                   | 101.93                    | 98.92                   | -.00725                  | .2428                   | -52         |
| -50         | 11.67                   | 6.154*    | 0.01124                  | 4.222                   | 89.00                      | 0.2368                    | -2.511                   | 101.66                    | 99.14                   | -0.00604                 | 0.2421                  | -50         |
| -48         | 12.34                   | 4.829*    | .01126                   | 4.014                   | 88.81                      | 0.2491                    | -2.012                   | 101.38                    | 99.37                   | -.00483                  | .2414                   | -48         |
| -46         | 13.06                   | 3.445*    | .01129                   | 3.818                   | 88.61                      | 0.2619                    | -1.511                   | 101.10                    | 99.59                   | -.00361                  | .2408                   | -46         |
| -44         | 13.71                   | 2.002*    | .01131                   | 3.633                   | 88.41                      | 0.2752                    | -1.009                   | 100.82                    | 99.81                   | -.00241                  | .2401                   | -44         |
| -42         | 14.45                   | 0.498*    | .01134                   | 3.460                   | 88.21                      | 0.2891                    | -0.505                   | 100.54                    | 100.04                  | -.00120                  | .2395                   | -42         |
| -40         | 15.22                   | 0.526     | 0.01136                  | 3.296                   | 88.01                      | 0.3034                    | 0.000                    | 100.26                    | 100.36                  | 0.00000                  | 0.2389                  | -40         |
| -38         | 16.02                   | 1.328     | .01139                   | 3.141                   | 87.81                      | 0.3184                    | 0.506                    | 99.97                     | 100.48                  | .00120                   | .2383                   | -38         |
| -36         | 16.86                   | 2.163     | .01142                   | 2.995                   | 87.60                      | 0.3338                    | 1.014                    | 99.68                     | 100.70                  | .00240                   | .2377                   | -36         |
| -34         | 17.73                   | 3.032     | .01144                   | 2.858                   | 87.40                      | 0.3499                    | 1.524                    | 99.39                     | 100.91                  | .00359                   | .2371                   | -34         |
| -32         | 18.63                   | 3.937     | .01147                   | 2.728                   | 87.20                      | 0.3666                    | 2.035                    | 99.10                     | 101.13                  | .00479                   | .2365                   | -32         |
| -30         | 19.57                   | 4.877     | 0.01150                  | 2.605                   | 86.99                      | 0.3839                    | 2.547                    | 98.80                     | 101.35                  | 0.00598                  | 0.2359                  | -30         |
| -28         | 20.55                   | 5.853     | .01152                   | 2.488                   | 86.79                      | 0.4018                    | 3.061                    | 98.50                     | 101.56                  | .00716                   | .2353                   | -28         |
| -26         | 21.56                   | 6.868     | .01155                   | 2.379                   | 86.58                      | 0.4204                    | 3.576                    | 98.20                     | 101.78                  | .00835                   | .2348                   | -26         |
| -24         | 22.62                   | 7.921     | .01158                   | 2.275                   | 86.37                      | 0.4396                    | 4.093                    | 97.90                     | 101.99                  | .00953                   | .2342                   | -24         |
| -22         | 23.71                   | 9.015     | .01161                   | 2.176                   | 86.17                      | 0.4596                    | 4.611                    | 97.59                     | 102.20                  | .01072                   | .2337                   | -22         |
| -20         | 24.85                   | 10.15     | 0.01163                  | 2.083                   | 85.96                      | 0.4802                    | 5.131                    | 97.29                     | 102.42                  | 0.01189                  | 0.2332                  | -20         |
| -18         | 26.02                   | 11.32     | .01166                   | 1.994                   | 85.75                      | 0.5015                    | 5.652                    | 96.97                     | 102.63                  | .01307                   | .2326                   | -18         |
| -16         | 27.24                   | 12.54     | .01169                   | 1.910                   | 85.54                      | 0.5236                    | 6.175                    | 96.66                     | 102.84                  | .01425                   | .2321                   | -16         |
| -14         | 28.50                   | 13.81     | .01172                   | 1.830                   | 85.33                      | 0.5464                    | 6.699                    | 96.34                     | 103.04                  | .01542                   | .2316                   | -14         |
| -12         | 29.81                   | 15.11     | .01175                   | 1.754                   | 85.11                      | 0.5700                    | 7.224                    | 96.03                     | 103.25                  | .01659                   | .2311                   | -12         |
| -10         | 31.16                   | 16.47     | 0.01178                  | 1.683                   | 84.90                      | 0.5944                    | 7.751                    | 95.70                     | 103.46                  | 0.01776                  | 0.2306                  | -10         |
| -8          | 32.56                   | 17.87     | .01181                   | 1.614                   | 84.69                      | 0.6195                    | 8.280                    | 95.38                     | 103.66                  | .01892                   | .2301                   | -8          |
| -6          | 34.01                   | 19.32     | .01184                   | 1.549                   | 84.47                      | 0.6456                    | 8.810                    | 95.05                     | 103.86                  | .02009                   | .2296                   | -6          |
| -4          | 35.51                   | 20.81     | .01187                   | 1.487                   | 84.26                      | 0.6724                    | 9.341                    | 94.72                     | 104.07                  | .02125                   | .2291                   | -4          |
| -2          | 37.06                   | 22.36     | .01190                   | 1.428                   | 84.04                      | 0.7001                    | 9.874                    | 94.39                     | 104.27                  | .02241                   | .2286                   | -2          |
| 0           | 38.66                   | 23.96     | 0.01193                  | 1.372                   | 83.83                      | 0.7287                    | 10.41                    | 94.06                     | 104.47                  | 0.02357                  | 0.2282                  | 0           |
| 2           | 40.31                   | 25.61     | .01196                   | 1.319                   | 83.61                      | 0.7582                    | 10.95                    | 93.72                     | 104.66                  | .02472                   | .2277                   | 2           |
| 4           | 42.01                   | 27.32     | .01199                   | 1.268                   | 83.39                      | 0.7887                    | 11.48                    | 93.38                     | 104.86                  | .02587                   | .2273                   | 4           |
| 6           | 43.78                   | 29.08     | .01202                   | 1.220                   | 83.17                      | 0.8200                    | 12.02                    | 93.03                     | 105.06                  | .02703                   | .2268                   | 6           |
| 8           | 45.59                   | 30.90     | .01206                   | 1.173                   | 82.95                      | 0.8524                    | 12.56                    | 92.69                     | 105.25                  | .02818                   | .2264                   | 8           |
| 10          | 47.46                   | 32.77     | 0.01209                  | 1.129                   | 82.72                      | 0.8857                    | 13.10                    | 92.34                     | 105.44                  | 0.02932                  | 0.2259                  | 10          |
| 12          | 49.40                   | 34.70     | .01212                   | 1.087                   | 82.50                      | 0.9201                    | 13.65                    | 91.99                     | 105.63                  | .03047                   | .2255                   | 12          |
| 14          | 51.39                   | 36.69     | .01215                   | 1.047                   | 82.28                      | 0.9554                    | 14.19                    | 91.63                     | 105.82                  | .03161                   | .2251                   | 14          |
| 16          | 53.44                   | 38.74     | .01219                   | 1.008                   | 82.05                      | 0.9919                    | 14.74                    | 91.27                     | 106.01                  | .03275                   | .2246                   | 16          |
| 18          | 55.55                   | 40.86     | .01222                   | 0.9714                  | 81.83                      | 1.029                     | 15.29                    | 90.91                     | 106.20                  | .03389                   | .2242                   | 18          |
| 20          | 57.73                   | 43.03     | 0.01226                  | 0.9363                  | 81.60                      | 1.068                     | 15.84                    | 90.55                     | 106.38                  | 0.03503                  | 0.2238                  | 20          |
| 22          | 59.97                   | 45.27     | .01229                   | 0.9027                  | 81.37                      | 1.108                     | 16.39                    | 90.18                     | 106.57                  | .03617                   | .2234                   | 22          |
| 24          | 62.27                   | 47.58     | .01233                   | 0.8706                  | 81.14                      | 1.149                     | 16.94                    | 89.81                     | 106.75                  | .03730                   | .2230                   | 24          |
| 26          | 64.64                   | 49.95     | .01236                   | 0.8398                  | 80.91                      | 1.191                     | 17.50                    | 89.43                     | 106.93                  | .03844                   | .2226                   | 26          |
| 28          | 67.08                   | 52.39     | .01240                   | 0.8103                  | 80.68                      | 1.234                     | 18.05                    | 89.06                     | 107.11                  | .03958                   | .2222                   | 28          |

\*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours &amp; Co. 1964



TABLE 4-PROPERTIES OF REFRIGERANT 22, LIQUID AND SATURATED VAPOR (Contd)

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| 30          | 69.59                   | 54.90     | 0.01243                  | 0.7821                  | 80.44                      | 1.279                     | 18.61                    | 88.67                     | 107.28                  | 0.04070                  | 0.2218                  | 30          |
| 32          | 72.17                   | 57.47     | .01247                   | 0.7550                  | 80.21                      | 1.324                     | 19.17                    | 88.29                     | 107.46                  | .04182                   | .2214                   | 32          |
| 34          | 74.82                   | 60.12     | .01251                   | 0.7291                  | 79.97                      | 1.372                     | 19.73                    | 87.90                     | 107.63                  | .04295                   | .2210                   | 34          |
| 36          | 77.54                   | 62.84     | .01254                   | 0.7043                  | 79.73                      | 1.420                     | 20.29                    | 87.51                     | 107.80                  | .04407                   | .2206                   | 36          |
| 38          | 80.34                   | 65.64     | .01258                   | 0.6804                  | 79.50                      | 1.470                     | 20.86                    | 87.12                     | 107.97                  | .04520                   | .2202                   | 38          |
| 40          | 83.21                   | 68.51     | 0.01262                  | 0.6575                  | 79.26                      | 1.521                     | 21.42                    | 86.72                     | 108.14                  | 0.04632                  | 0.2199                  | 40          |
| 42          | 86.15                   | 71.46     | .01266                   | 0.6356                  | 79.01                      | 1.573                     | 21.99                    | 86.32                     | 108.31                  | .04744                   | .2195                   | 42          |
| 44          | 89.18                   | 74.48     | .01270                   | 0.6149                  | 78.77                      | 1.627                     | 22.56                    | 85.91                     | 108.47                  | .04855                   | .2191                   | 44          |
| 46          | 92.28                   | 77.58     | .01274                   | 0.5942                  | 78.53                      | 1.683                     | 23.13                    | 85.51                     | 108.63                  | .04967                   | .2188                   | 46          |
| 48          | 95.46                   | 80.77     | .01278                   | 0.5748                  | 78.28                      | 1.740                     | 23.70                    | 85.09                     | 108.80                  | .05079                   | .2184                   | 48          |
| 50          | 98.73                   | 84.03     | 0.01282                  | 0.5561                  | 78.03                      | 1.798                     | 24.28                    | 84.68                     | 108.95                  | 0.05190                  | 0.2180                  | 50          |
| 52          | 102.07                  | 87.38     | .01286                   | 0.5381                  | 77.78                      | 1.859                     | 24.85                    | 84.26                     | 109.11                  | .05301                   | .2177                   | 52          |
| 54          | 105.50                  | 90.81     | .01290                   | 0.5208                  | 77.53                      | 1.920                     | 25.43                    | 83.83                     | 109.26                  | .05412                   | .2173                   | 54          |
| 56          | 109.02                  | 94.32     | .01294                   | 0.5041                  | 77.28                      | 1.984                     | 26.01                    | 83.41                     | 109.42                  | .05523                   | .2170                   | 56          |
| 58          | 112.62                  | 97.93     | .01298                   | 0.4881                  | 77.03                      | 2.049                     | 26.59                    | 82.98                     | 109.56                  | .05634                   | .2166                   | 58          |
| 60          | 116.31                  | 101.62    | 0.01303                  | 0.4727                  | 76.77                      | 2.115                     | 27.17                    | 82.54                     | 109.71                  | 0.05745                  | 0.2163                  | 60          |
| 62          | 120.09                  | 105.39    | .01307                   | 0.4579                  | 76.52                      | 2.184                     | 27.76                    | 82.10                     | 109.86                  | .05855                   | .2159                   | 62          |
| 64          | 123.96                  | 109.26    | .01311                   | 0.4436                  | 76.26                      | 2.254                     | 28.34                    | 81.66                     | 110.00                  | .05966                   | .2156                   | 64          |
| 66          | 127.92                  | 113.22    | .01316                   | 0.4298                  | 76.00                      | 2.327                     | 28.93                    | 81.21                     | 110.14                  | .06076                   | .2152                   | 66          |
| 68          | 131.97                  | 117.28    | .01320                   | 0.4165                  | 75.73                      | 2.401                     | 29.52                    | 80.76                     | 110.28                  | .06186                   | .2149                   | 68          |
| 70          | 136.12                  | 121.43    | 0.01325                  | 0.4037                  | 75.47                      | 2.477                     | 30.12                    | 80.30                     | 110.41                  | 0.06296                  | 0.2146                  | 70          |
| 72          | 140.37                  | 125.67    | .01330                   | 0.3914                  | 75.20                      | 2.555                     | 30.71                    | 79.84                     | 110.55                  | .06406                   | .2142                   | 72          |
| 74          | 144.71                  | 130.01    | .01335                   | 0.3795                  | 74.93                      | 2.635                     | 31.31                    | 79.37                     | 110.68                  | .06516                   | .2139                   | 74          |
| 76          | 149.15                  | 134.45    | .01339                   | 0.3680                  | 74.66                      | 2.717                     | 31.91                    | 78.90                     | 110.81                  | .06626                   | .2136                   | 76          |
| 78          | 153.69                  | 138.99    | .01344                   | 0.3569                  | 74.39                      | 2.802                     | 32.51                    | 78.42                     | 110.93                  | .06736                   | .2132                   | 78          |
| 80          | 158.33                  | 143.63    | 0.01349                  | 0.3462                  | 74.12                      | 2.889                     | 33.11                    | 77.94                     | 111.05                  | 0.06846                  | 0.2129                  | 80          |
| 82          | 163.07                  | 148.37    | .01354                   | 0.3359                  | 73.84                      | 2.977                     | 33.71                    | 77.46                     | 111.17                  | .06956                   | .2126                   | 82          |
| 84          | 167.92                  | 153.22    | .01359                   | 0.3259                  | 73.56                      | 3.069                     | 34.32                    | 76.97                     | 111.29                  | .07065                   | .2122                   | 84          |
| 86          | 172.87                  | 158.17    | .01365                   | 0.3162                  | 73.28                      | 3.162                     | 34.93                    | 76.47                     | 111.40                  | .07175                   | .2119                   | 86          |
| 88          | 177.93                  | 163.23    | .01370                   | 0.3069                  | 72.99                      | 3.258                     | 35.54                    | 75.97                     | 111.51                  | .07285                   | .2116                   | 88          |
| 90          | 183.09                  | 168.40    | 0.01375                  | 0.2979                  | 72.71                      | 3.357                     | 36.16                    | 75.46                     | 111.62                  | 0.07394                  | 0.2112                  | 90          |
| 92          | 188.37                  | 173.67    | .01381                   | 0.2892                  | 72.41                      | 3.458                     | 36.77                    | 74.95                     | 111.72                  | .07504                   | .2109                   | 92          |
| 94          | 193.76                  | 179.06    | .01386                   | 0.2807                  | 72.13                      | 3.562                     | 37.39                    | 74.43                     | 111.82                  | .07613                   | .2106                   | 94          |
| 96          | 199.26                  | 184.56    | .01392                   | 0.2726                  | 71.83                      | 3.669                     | 38.02                    | 73.91                     | 111.92                  | .07723                   | .2102                   | 96          |
| 98          | 204.87                  | 190.18    | .01398                   | 0.2647                  | 71.54                      | 3.778                     | 38.64                    | 73.38                     | 112.02                  | .07832                   | .2099                   | 98          |
| 100         | 210.60                  | 195.91    | 0.01404                  | 0.2570                  | 71.24                      | 3.891                     | 39.27                    | 72.84                     | 112.11                  | 0.07942                  | 0.2096                  | 100         |
| 102         | 216.45                  | 201.76    | .01410                   | 0.2496                  | 70.93                      | 4.006                     | 39.90                    | 72.29                     | 112.19                  | .08052                   | .2092                   | 102         |
| 104         | 222.42                  | 207.72    | .01416                   | 0.2424                  | 70.63                      | 4.125                     | 40.53                    | 71.74                     | 112.27                  | .08161                   | .2089                   | 104         |
| 106         | 228.50                  | 213.81    | .01422                   | 0.2355                  | 70.32                      | 4.247                     | 41.17                    | 71.19                     | 112.35                  | .08271                   | .2086                   | 106         |
| 108         | 234.71                  | 220.02    | .01429                   | 0.2288                  | 70.01                      | 4.372                     | 41.80                    | 70.62                     | 112.43                  | .08381                   | .2082                   | 108         |
| 110         | 241.04                  | 226.35    | 0.01435                  | 0.2222                  | 69.69                      | 4.500                     | 42.45                    | 70.05                     | 112.50                  | 0.08491                  | 0.2079                  | 110         |
| 112         | 247.50                  | 232.80    | .01442                   | 0.2159                  | 69.40                      | 4.632                     | 43.09                    | 69.47                     | 112.56                  | .08601                   | .2075                   | 112         |
| 114         | 254.08                  | 239.38    | .01448                   | 0.2097                  | 69.05                      | 4.768                     | 43.74                    | 68.89                     | 112.63                  | .08711                   | .2072                   | 114         |
| 116         | 260.79                  | 246.10    | .01455                   | 0.2038                  | 68.72                      | 4.907                     | 44.39                    | 68.29                     | 112.68                  | .08821                   | .2068                   | 116         |
| 118         | 267.63                  | 252.94    | .01462                   | 0.1980                  | 68.39                      | 5.051                     | 45.05                    | 67.69                     | 112.74                  | .08932                   | .2065                   | 118         |
| 120         | 274.60                  | 259.91    | 0.01469                  | 0.1924                  | 68.05                      | 5.198                     | 45.71                    | 67.08                     | 112.78                  | 0.09042                  | 0.2061                  | 120         |
| 122         | 281.71                  | 267.01    | .01477                   | 0.1869                  | 67.71                      | 5.350                     | 46.37                    | 66.46                     | 112.82                  | .09153                   | .2058                   | 122         |
| 124         | 288.95                  | 274.25    | .01484                   | 0.1816                  | 67.37                      | 5.506                     | 47.03                    | 65.83                     | 112.86                  | .09264                   | .2054                   | 124         |
| 126         | 296.33                  | 281.63    | .01492                   | 0.1765                  | 67.02                      | 5.667                     | 47.71                    | 65.19                     | 112.89                  | .09375                   | .2051                   | 126         |
| 128         | 303.84                  | 289.14    | .01500                   | 0.1715                  | 66.67                      | 5.832                     | 48.38                    | 64.54                     | 112.92                  | .09487                   | .2047                   | 128         |
| 130         | 311.50                  | 296.80    | 0.01508                  | 0.1666                  | 66.31                      | 6.002                     | 49.06                    | 63.88                     | 112.94                  | 0.09598                  | 0.2043                  | 130         |
| 132         | 319.29                  | 304.60    | .01516                   | 0.1619                  | 65.95                      | 6.178                     | 49.74                    | 63.21                     | 112.95                  | .09711                   | .2039                   | 132         |
| 134         | 327.23                  | 312.54    | .01525                   | 0.1573                  | 65.58                      | 6.359                     | 50.43                    | 62.52                     | 112.96                  | .09823                   | .2035                   | 134         |
| 136         | 335.32                  | 320.63    | .01534                   | 0.1528                  | 65.21                      | 6.545                     | 51.13                    | 61.83                     | 112.95                  | .09936                   | .2032                   | 136         |
| 138         | 343.56                  | 328.86    | .01543                   | 0.1484                  | 64.83                      | 6.737                     | 51.82                    | 61.12                     | 112.95                  | .1005                    | .2028                   | 138         |
| 140         | 351.94                  | 337.25    | 0.01552                  | 0.1442                  | 64.44                      | 6.936                     | 52.53                    | 60.40                     | 112.93                  | 0.1016                   | 0.2024                  | 140         |
| 142         | 360.48                  | 345.79    | .01561                   | 0.1400                  | 64.05                      | 7.141                     | 53.24                    | 59.67                     | 112.91                  | .1028                    | .2019                   | 142         |
| 144         | 369.17                  | 354.48    | .01571                   | 0.1360                  | 63.65                      | 7.353                     | 53.96                    | 58.92                     | 112.88                  | .1039                    | .2015                   | 144         |
| 146         | 378.02                  | 363.32    | .01581                   | 0.1321                  | 63.24                      | 7.572                     | 54.68                    | 58.16                     | 112.84                  | .1051                    | .2011                   | 146         |
| 148         | 387.03                  | 372.33    | .01592                   | 0.1282                  | 62.83                      | 7.799                     | 55.41                    | 57.38                     | 112.79                  | .1062                    | .2007                   | 148         |
| 150         | 396.19                  | 381.50    | 0.01603                  | 0.1245                  | 62.40                      | 8.033                     | 56.14                    | 56.59                     | 112.73                  | 0.1074                   | 0.2002                  | 150         |
| 152         | 405.52                  | 390.83    | .01614                   | 0.1208                  | 61.97                      | 8.276                     | 56.89                    | 55.77                     | 112.66                  | .1086                    | .1997                   | 152         |
| 154         | 415.02                  | 400.32    | .01625                   | 0.1173                  | 61.53                      | 8.528                     | 57.64                    | 54.94                     | 112.58                  | .1097                    | .1993                   | 154         |
| 156         | 424.68                  | 409.99    | .01637                   | 0.1138                  | 61.08                      | 8.790                     | 58.40                    | 54.09                     | 112.49                  | .1109                    | .1988                   | 156         |
| 158         | 434.52                  | 419.82    | .01650                   | 0.1104                  | 60.62                      | 9.062                     | 59.17                    | 53.21                     | 112.38                  | .1121                    | .1983                   | 158         |
| 160         | 444.53                  | 429.83    | 0.01663                  | 0.1070                  | 60.15                      | 9.345                     | 59.95                    | 52.32                     | 112.26                  | 0.1133                   | 0.1978                  | 160         |



TABLE 5-PROPERTIES OF REFRIGERANT 11, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| — 40        | 0.7432                  | 28.41*    | .009873                  | 43.92                   | 101.28                     | 0.02277                   | 0.000                    | 87.19                     | 87.19                   | 0.000000                 | 0.2078                  | — 40        |
| — 38        | 0.7958                  | 28.30*    | .009888                  | 41.20                   | 101.14                     | 0.02427                   | 0.404                    | 87.03                     | 87.43                   | .000960                  | .2073                   | — 38        |
| — 36        | 0.8515                  | 28.19*    | .009902                  | 38.68                   | 100.99                     | 0.02586                   | 0.808                    | 86.86                     | 87.67                   | .001915                  | .2069                   | — 36        |
| — 34        | 0.9105                  | 28.07*    | .009917                  | 36.33                   | 100.84                     | 0.02752                   | 1.212                    | 86.69                     | 87.90                   | .002867                  | .2065                   | — 34        |
| — 32        | 0.9728                  | 27.94*    | .009932                  | 34.16                   | 100.69                     | 0.02928                   | 1.616                    | 86.52                     | 88.14                   | .003814                  | .2061                   | — 32        |
| — 30        | 1.039                   | 27.81*    | .009946                  | 32.13                   | 100.54                     | 0.03112                   | 2.020                    | 86.36                     | 88.38                   | .004756                  | .2057                   | — 30        |
| — 28        | 1.108                   | 27.67*    | .009961                  | 30.25                   | 100.39                     | 0.03306                   | 2.425                    | 86.19                     | 88.62                   | .005695                  | .2054                   | — 28        |
| — 26        | 1.181                   | 27.52*    | .009976                  | 28.50                   | 100.24                     | 0.03509                   | 2.829                    | 86.03                     | 88.85                   | .006629                  | .2050                   | — 26        |
| — 24        | 1.259                   | 27.36*    | .009991                  | 26.86                   | 100.09                     | 0.03723                   | 3.233                    | 85.86                     | 89.09                   | .007559                  | .2046                   | — 24        |
| — 22        | 1.340                   | 27.19*    | .01001                   | 25.34                   | 99.94                      | 0.03947                   | 3.638                    | 85.69                     | 89.33                   | .008485                  | .2043                   | — 22        |
| — 20        | 1.426                   | 27.02*    | .01002                   | 23.91                   | 99.79                      | 0.04182                   | 4.043                    | 85.53                     | 89.57                   | .009408                  | .2039                   | — 20        |
| — 18        | 1.516                   | 26.83*    | .01004                   | 22.59                   | 99.64                      | 0.04428                   | 4.448                    | 85.36                     | 89.81                   | .01033                   | .2036                   | — 18        |
| — 16        | 1.611                   | 26.64*    | .01005                   | 21.34                   | 99.49                      | 0.04685                   | 4.852                    | 85.20                     | 90.05                   | .01124                   | .2033                   | — 16        |
| — 14        | 1.711                   | 26.44*    | .01007                   | 20.18                   | 99.33                      | 0.04955                   | 5.258                    | 85.03                     | 90.29                   | .01215                   | .2029                   | — 14        |
| — 12        | 1.815                   | 26.23*    | .01008                   | 19.10                   | 99.18                      | 0.05237                   | 5.663                    | 84.87                     | 90.53                   | .01306                   | .2026                   | — 12        |
| — 10        | 1.925                   | 26.00*    | .01010                   | 18.08                   | 99.03                      | 0.05531                   | 6.068                    | 84.70                     | 90.77                   | .01396                   | .2023                   | — 10        |
| — 8         | 2.041                   | 25.77*    | .01011                   | 17.13                   | 98.88                      | 0.05839                   | 6.474                    | 84.54                     | 91.01                   | .01486                   | .2020                   | — 8         |
| — 6         | 2.162                   | 25.52*    | .01013                   | 16.23                   | 98.73                      | 0.06161                   | 6.879                    | 84.37                     | 91.25                   | .01576                   | .2017                   | — 6         |
| — 4         | 2.289                   | 25.26*    | .01015                   | 15.39                   | 98.57                      | 0.06497                   | 7.285                    | 84.20                     | 91.49                   | .01665                   | .2014                   | — 4         |
| — 2         | 2.422                   | 24.99*    | .01016                   | 14.61                   | 98.42                      | 0.06847                   | 7.691                    | 84.04                     | 91.73                   | .01754                   | .2012                   | — 2         |
| 0           | 2.561                   | 24.71*    | .01018                   | 13.87                   | 98.27                      | 0.07212                   | 8.098                    | 83.87                     | 91.97                   | .01842                   | .2009                   | 0           |
| 2           | 2.706                   | 24.41*    | .01019                   | 13.17                   | 98.12                      | 0.07593                   | 8.504                    | 83.71                     | 92.21                   | .01930                   | .2006                   | 2           |
| 4           | 2.859                   | 24.10*    | .01021                   | 12.52                   | 97.96                      | 0.07989                   | 8.910                    | 83.54                     | 92.45                   | .02018                   | .2004                   | 4           |
| 6           | 3.018                   | 23.78*    | .01022                   | 11.90                   | 97.81                      | 0.08402                   | 9.317                    | 83.38                     | 92.69                   | .02106                   | .2001                   | 6           |
| 8           | 3.184                   | 23.44*    | .01024                   | 11.32                   | 97.65                      | 0.08832                   | 9.724                    | 83.21                     | 92.93                   | .02193                   | .1999                   | 8           |
| 10          | 3.358                   | 23.08*    | .01026                   | 10.78                   | 97.50                      | 0.09279                   | 10.13                    | 83.04                     | 93.18                   | .02280                   | .1996                   | 10          |
| 12          | 3.539                   | 22.72*    | .01027                   | 10.26                   | 97.34                      | 0.09743                   | 10.54                    | 82.88                     | 93.42                   | .02366                   | .1994                   | 12          |
| 14          | 3.728                   | 22.33*    | .01029                   | 9.779                   | 97.19                      | 0.1023                    | 10.95                    | 82.71                     | 93.66                   | .02452                   | .1991                   | 14          |
| 16          | 3.926                   | 21.93*    | .01031                   | 9.321                   | 97.03                      | 0.1073                    | 11.35                    | 82.55                     | 93.90                   | .02538                   | .1989                   | 16          |
| 18          | 4.131                   | 21.51*    | .01032                   | 8.889                   | 96.88                      | 0.1125                    | 11.76                    | 82.38                     | 94.14                   | .02623                   | .1987                   | 18          |
| 20          | 4.346                   | 21.07*    | .01034                   | 8.481                   | 96.72                      | 0.1179                    | 12.17                    | 82.21                     | 94.38                   | .02709                   | .1985                   | 20          |
| 22          | 4.569                   | 20.62*    | .01036                   | 8.095                   | 96.57                      | 0.1235                    | 12.58                    | 82.05                     | 94.62                   | .02794                   | .1983                   | 22          |
| 24          | 4.801                   | 20.15*    | .01037                   | 7.731                   | 96.41                      | 0.1294                    | 12.99                    | 81.88                     | 94.86                   | .02878                   | .1981                   | 24          |
| 26          | 5.043                   | 19.65*    | .01039                   | 7.386                   | 96.25                      | 0.1354                    | 13.40                    | 81.71                     | 95.11                   | .02962                   | .1979                   | 26          |
| 28          | 5.294                   | 19.14*    | .01041                   | 7.060                   | 96.10                      | 0.1417                    | 13.81                    | 81.54                     | 95.35                   | .03046                   | .1977                   | 28          |
| 30          | 5.556                   | 18.61*    | .01042                   | 6.750                   | 95.94                      | 0.1481                    | 14.21                    | 81.37                     | 95.59                   | .03130                   | .1975                   | 30          |
| 32          | 5.827                   | 18.06*    | .01044                   | 6.457                   | 95.78                      | 0.1549                    | 14.62                    | 81.21                     | 95.83                   | .03213                   | .1973                   | 32          |
| 34          | 6.109                   | 17.48*    | .01046                   | 6.180                   | 95.62                      | 0.1618                    | 15.03                    | 81.04                     | 96.07                   | .03296                   | .1971                   | 34          |
| 36          | 6.403                   | 16.89*    | .01048                   | 5.917                   | 95.46                      | 0.1690                    | 15.44                    | 80.87                     | 96.31                   | .03379                   | .1969                   | 36          |
| 38          | 6.707                   | 16.27*    | .01049                   | 5.667                   | 95.31                      | 0.1765                    | 15.85                    | 80.70                     | 96.55                   | .03462                   | .1968                   | 38          |
| 40          | 7.022                   | 15.62*    | .01051                   | 5.430                   | 95.15                      | 0.1842                    | 16.26                    | 80.53                     | 96.79                   | .03544                   | .1966                   | 40          |
| 42          | 7.350                   | 14.96*    | .01053                   | 5.205                   | 94.99                      | 0.1921                    | 16.68                    | 80.36                     | 97.04                   | .03626                   | .1964                   | 42          |
| 44          | 7.689                   | 14.27*    | .01055                   | 4.991                   | 94.83                      | 0.2004                    | 17.09                    | 80.19                     | 97.28                   | .03707                   | .1963                   | 44          |
| 46          | 8.041                   | 13.55*    | .01056                   | 4.788                   | 94.67                      | 0.2089                    | 17.50                    | 80.02                     | 97.52                   | .03789                   | .1961                   | 46          |
| 48          | 8.405                   | 12.81*    | .01058                   | 4.594                   | 94.51                      | 0.2177                    | 17.91                    | 79.85                     | 97.76                   | .03870                   | .1960                   | 48          |
| 50          | 8.783                   | 12.04*    | .01060                   | 4.411                   | 94.35                      | 0.2267                    | 18.32                    | 79.68                     | 98.00                   | .03951                   | .1958                   | 50          |
| 52          | 9.173                   | 11.24*    | .01062                   | 4.236                   | 94.19                      | 0.2361                    | 18.73                    | 79.51                     | 98.24                   | .04031                   | .1957                   | 52          |
| 54          | 9.578                   | 10.42*    | .01064                   | 4.069                   | 94.03                      | 0.2458                    | 19.14                    | 79.33                     | 98.48                   | .04111                   | .1956                   | 54          |
| 56          | 9.996                   | 9.569*    | .01065                   | 3.910                   | 93.86                      | 0.2557                    | 19.56                    | 79.16                     | 98.72                   | .04191                   | .1954                   | 56          |
| 58          | 10.43                   | 8.688*    | .01067                   | 3.759                   | 93.70                      | 0.2660                    | 19.97                    | 78.99                     | 98.96                   | .04271                   | .1953                   | 58          |
| 60          | 10.88                   | 7.778*    | .01069                   | 3.615                   | 93.54                      | 0.2766                    | 20.38                    | 78.82                     | 99.20                   | .04350                   | .1952                   | 60          |
| 62          | 11.34                   | 6.836*    | .01071                   | 3.478                   | 93.38                      | 0.2875                    | 20.80                    | 78.64                     | 99.44                   | .04430                   | .1951                   | 62          |
| 64          | 11.82                   | 5.864*    | .01073                   | 3.347                   | 93.21                      | 0.2988                    | 21.21                    | 78.47                     | 99.68                   | .04509                   | .1949                   | 64          |
| 66          | 12.31                   | 4.859*    | .01075                   | 3.222                   | 93.05                      | 0.3104                    | 21.62                    | 78.29                     | 99.92                   | .04587                   | .1948                   | 66          |
| 68          | 12.82                   | 3.822*    | .01077                   | 3.102                   | 92.89                      | 0.3224                    | 22.04                    | 78.12                     | 100.15                  | .04666                   | .1947                   | 68          |
| 70          | 13.35                   | 2.752*    | .01079                   | 2.988                   | 92.72                      | 0.3347                    | 22.45                    | 77.94                     | 100.39                  | .04744                   | .1946                   | 70          |
| 72          | 13.89                   | 1.647*    | .01080                   | 2.879                   | 92.56                      | 0.3473                    | 22.87                    | 77.77                     | 100.63                  | .04822                   | .1945                   | 72          |
| 74          | 14.45                   | 0.507*    | .01082                   | 2.775                   | 92.39                      | 0.3603                    | 23.28                    | 77.59                     | 100.87                  | .04899                   | .1944                   | 74          |
| 76          | 15.02                   | 0.328     | .01084                   | 2.676                   | 92.23                      | 0.3738                    | 23.70                    | 77.41                     | 101.11                  | .04977                   | .1943                   | 76          |
| 78          | 15.62                   | 0.923     | .01086                   | 2.580                   | 92.06                      | 0.3875                    | 24.11                    | 77.23                     | 101.35                  | .05054                   | .1942                   | 78          |
| 80          | 16.23                   | 1.537     | .01088                   | 2.489                   | 91.90                      | 0.4017                    | 24.53                    | 77.06                     | 101.58                  | .05131                   | .1941                   | 80          |
| 82          | 16.87                   | 2.169     | .01090                   | 2.402                   | 91.73                      | 0.4163                    | 24.94                    | 76.88                     | 101.82                  | .05208                   | .1940                   | 82          |
| 84          | 17.52                   | 2.820     | .01092                   | 2.319                   | 91.56                      | 0.4313                    | 25.36                    | 76.70                     | 102.06                  | .05284                   | .1939                   | 84          |
| 86          | 18.19                   | 3.490     | .01094                   | 2.239                   | 91.39                      | 0.4467                    | 25.78                    | 76.52                     | 102.29                  | .05360                   | .1938                   | 86          |
| 88          | 18.88                   | 4.180     | .01096                   | 2.162                   | 91.23                      | 0.4625                    | 26.19                    | 76.34                     | 102.53                  | .05436                   | .1938                   | 88          |
| 90          | 19.59                   | 4.891     | .01098                   | 2.089                   | 91.06                      | 0.4787                    | 26.61                    | 76.16                     | 102.77                  | .05512                   | .1937                   | 90          |
| 92          | 20.32                   | 5.622     | .01100                   | 2.018                   | 90.89                      | 0.4954                    | 27.03                    | 75.97                     | 103.00                  | .05588                   | .1936                   | 92          |
| 94          | 21.07                   | 6.374     | .01102                   | 1.951                   | 90.72                      | 0.5126                    | 27.45                    | 75.79                     | 103.24                  | .05663                   | .1935                   | 94          |
| 96          | 21.84                   | 7.147     | .01104                   | 1.886                   | 90.55                      | 0.5302                    | 27.86                    | 75.61                     | 103.47                  | .05738                   | .1935                   | 96          |
| 98          | 22.64                   | 7.942     | .01106                   | 1.824                   | 90.38                      | 0.5482                    | 28.28                    | 75.42                     | 103.71                  | .05813                   | .1934                   | 98          |

\*Inches of mercury below one atmosphere.

Courtesy of

Carrier Airconditioning Company





TABLE 5-PROPERTIES OF REFRIGERANT 11, LIQUID AND SATURATED VAPOR (Contd)

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| 100         | 23.46                   | 8.760     | 0.01109                  | 1.765                   | 90.21                      | 0.5667                    | 28.70                    | 75.24                     | 103.94                  | 0.05888                  | 0.1933                  | 100         |
| 102         | 24.30                   | 9.600     | .01111                   | 1.707                   | 90.04                      | 0.5857                    | 29.12                    | 75.06                     | 104.17                  | .05962                   | .1933                   | 102         |
| 104         | 25.16                   | 10.46     | .01113                   | 1.652                   | 89.87                      | 0.6052                    | 29.54                    | 74.87                     | 104.41                  | .06036                   | .1932                   | 104         |
| 106         | 26.05                   | 11.35     | .01115                   | 1.600                   | 89.69                      | 0.6252                    | 29.96                    | 74.68                     | 104.64                  | .06110                   | .1931                   | 106         |
| 108         | 26.96                   | 12.26     | .01117                   | 1.549                   | 89.52                      | 0.6457                    | 30.38                    | 74.50                     | 104.87                  | .06184                   | .1931                   | 108         |
| 110         | 27.89                   | 13.19     | 0.01119                  | 1.500                   | 89.35                      | 0.6667                    | 30.80                    | 74.31                     | 105.11                  | 0.06258                  | 0.1930                  | 110         |
| 112         | 28.85                   | 14.15     | .01121                   | 1.453                   | 89.18                      | 0.6882                    | 31.22                    | 74.12                     | 105.38                  | .06331                   | .1930                   | 112         |
| 114         | 29.83                   | 15.14     | .01124                   | 1.408                   | 89.00                      | 0.7103                    | 31.64                    | 73.93                     | 105.57                  | .06404                   | .1929                   | 114         |
| 116         | 30.84                   | 16.15     | .01125                   | 1.365                   | 88.83                      | 0.7329                    | 30.06                    | 73.74                     | 105.80                  | .06477                   | .1929                   | 116         |
| 118         | 31.88                   | 17.18     | .01128                   | 1.323                   | 88.65                      | 0.7561                    | 32.48                    | 73.55                     | 106.03                  | .06550                   | .1928                   | 118         |
| 120         | 32.94                   | 18.25     | 0.01130                  | 1.282                   | 88.48                      | 0.7798                    | 32.91                    | 73.36                     | 106.26                  | 0.06622                  | 0.1928                  | 120         |
| 122         | 34.03                   | 19.34     | .01133                   | 1.244                   | 88.30                      | 0.8041                    | 33.33                    | 73.16                     | 106.49                  | .06695                   | .1927                   | 122         |
| 124         | 35.15                   | 20.45     | .01135                   | 1.206                   | 88.12                      | 0.8289                    | 33.75                    | 72.97                     | 106.72                  | .06767                   | .1927                   | 124         |
| 126         | 36.29                   | 21.60     | .01137                   | 1.170                   | 87.95                      | 0.8544                    | 34.17                    | 72.77                     | 106.95                  | .06839                   | .1927                   | 126         |
| 128         | 37.47                   | 22.77     | .01139                   | 1.136                   | 87.77                      | 0.8805                    | 34.60                    | 72.58                     | 107.18                  | .06911                   | .1926                   | 128         |
| 130         | 38.67                   | 23.97     | 0.01142                  | 1.102                   | 87.59                      | 0.9071                    | 35.02                    | 72.38                     | 107.40                  | 0.06982                  | 0.1926                  | 130         |
| 132         | 39.90                   | 25.20     | .01140                   | 1.070                   | 87.41                      | 0.9344                    | 35.45                    | 72.19                     | 107.63                  | .07054                   | .1925                   | 132         |
| 134         | 41.16                   | 26.46     | .01146                   | 1.039                   | 87.23                      | 0.9624                    | 35.87                    | 71.99                     | 107.86                  | .07125                   | .1925                   | 134         |
| 136         | 42.45                   | 27.75     | .01149                   | 1.009                   | 87.05                      | 0.9909                    | 36.30                    | 71.79                     | 108.08                  | .07196                   | .1925                   | 136         |
| 138         | 43.77                   | 29.08     | .01151                   | 0.9802                  | 86.87                      | 1.020                     | 36.72                    | 71.59                     | 108.31                  | .07267                   | .1925                   | 138         |
| 140         | 45.12                   | 30.43     | 0.01154                  | 0.9523                  | 86.69                      | 1.050                     | 37.15                    | 71.39                     | 108.54                  | 0.07337                  | 0.1924                  | 140         |
| 142         | 46.51                   | 31.81     | .01156                   | 0.9254                  | 86.51                      | 1.081                     | 37.57                    | 71.19                     | 108.76                  | .07408                   | .1924                   | 142         |
| 144         | 47.92                   | 33.23     | .01158                   | 0.8994                  | 86.32                      | 1.112                     | 38.00                    | 70.98                     | 108.98                  | .07478                   | .1924                   | 144         |
| 146         | 49.37                   | 34.67     | .01161                   | 0.8742                  | 86.14                      | 1.144                     | 38.43                    | 70.78                     | 109.21                  | .07548                   | .1924                   | 146         |
| 148         | 50.85                   | 36.15     | .01163                   | 0.8500                  | 85.96                      | 1.177                     | 38.86                    | 70.57                     | 109.43                  | .07618                   | .1923                   | 148         |
| 150         | 52.36                   | 37.67     | 0.01166                  | 0.8265                  | 85.77                      | 1.210                     | 39.28                    | 70.37                     | 109.65                  | 0.07688                  | 0.1923                  | 150         |
| 152         | 53.91                   | 39.22     | .01168                   | 0.8038                  | 85.59                      | 1.244                     | 39.71                    | 70.16                     | 109.87                  | .07758                   | .1923                   | 152         |
| 154         | 55.49                   | 40.80     | .01171                   | 0.7819                  | 85.40                      | 1.279                     | 40.14                    | 69.95                     | 110.10                  | .07828                   | .1923                   | 154         |
| 156         | 57.11                   | 42.42     | .01174                   | 0.7607                  | 85.21                      | 1.315                     | 40.57                    | 69.74                     | 110.32                  | .07897                   | .1923                   | 156         |
| 158         | 58.76                   | 44.07     | .01176                   | 0.7402                  | 85.03                      | 1.351                     | 41.00                    | 69.53                     | 110.54                  | .07966                   | .1922                   | 158         |
| 160         | 60.45                   | 45.76     | .01179                   | 0.7204                  | 84.84                      | 1.388                     | 41.43                    | 69.32                     | 110.76                  | .08035                   | .1922                   | 160         |



TABLE 6-PROPERTIES OF REFRIGERANT 113, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>p | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| -30         | 0.2987                  | 29.31*    | 0.00947                  | 82.26                   | 105.64                     | 0.01216                   | 1.97                     | 72.68                     | 74.65                   | 0.0047                   | 0.1738                  | -30         |
| -28         | 0.3214                  | 29.27*    | .00948                   | 76.81                   | 105.50                     | .01302                    | 2.36                     | 72.57                     | 74.93                   | .0056                    | .1737                   | -28         |
| -26         | 0.3458                  | 29.22*    | .00949                   | 71.71                   | 105.37                     | .01395                    | 2.76                     | 72.45                     | 75.21                   | .0065                    | .1736                   | -26         |
| -24         | 0.3718                  | 29.16*    | .00950                   | 66.99                   | 105.23                     | .01493                    | 3.16                     | 72.33                     | 75.49                   | .0074                    | .1735                   | -24         |
| -22         | 0.3995                  | 29.11*    | .00952                   | 62.63                   | 105.09                     | .01597                    | 3.56                     | 72.21                     | 75.77                   | .0083                    | .1733                   | -22         |
| -20         | 0.4288                  | 29.05*    | 0.00953                  | 58.61                   | 104.96                     | 0.01706                   | 3.96                     | 72.09                     | 76.05                   | 0.0092                   | 0.1732                  | -20         |
| -18         | 0.4600                  | 28.98*    | .00954                   | 54.88                   | 104.82                     | .01822                    | 4.36                     | 71.98                     | 76.34                   | .0101                    | .1731                   | -18         |
| -16         | 0.4931                  | 28.92*    | .00955                   | 51.42                   | 104.68                     | .01945                    | 4.76                     | 71.86                     | 76.62                   | .0110                    | .1730                   | -16         |
| -14         | 0.5280                  | 28.85*    | .00957                   | 48.23                   | 104.54                     | .02074                    | 5.16                     | 71.74                     | 76.90                   | .0119                    | .1729                   | -14         |
| -12         | 0.5652                  | 28.77*    | .00958                   | 45.25                   | 104.40                     | .02210                    | 5.56                     | 71.62                     | 77.18                   | .0128                    | .1729                   | -12         |
| -10         | 0.6046                  | 28.69*    | 0.00959                  | 42.48                   | 104.26                     | 0.02354                   | 5.96                     | 71.51                     | 77.47                   | 0.0137                   | 0.1728                  | -10         |
| -8          | 0.6462                  | 28.60*    | .00960                   | 39.92                   | 104.12                     | .02505                    | 6.36                     | 71.39                     | 77.75                   | .0146                    | .1727                   | -8          |
| -6          | 0.6902                  | 28.51*    | .00962                   | 37.54                   | 103.98                     | .02664                    | 6.76                     | 71.27                     | 78.03                   | .0155                    | .1726                   | -6          |
| -4          | 0.7369                  | 28.42*    | .00963                   | 35.31                   | 103.84                     | .02832                    | 7.17                     | 71.15                     | 78.32                   | .0164                    | .1726                   | -4          |
| -2          | 0.7860                  | 28.32*    | .00964                   | 33.24                   | 103.70                     | .03009                    | 7.57                     | 71.03                     | 78.60                   | .0173                    | .1725                   | -2          |
| 0           | 0.8377                  | 28.21*    | 0.00966                  | 31.31                   | 103.56                     | 0.03194                   | 7.98                     | 70.92                     | 78.89                   | 0.0182                   | 0.1725                  | 0           |
| 2           | 0.8924                  | 28.10*    | .00967                   | 29.52                   | 103.41                     | .03388                    | 8.38                     | 70.80                     | 79.18                   | .0190                    | .1724                   | 2           |
| 4           | 0.9503                  | 27.99*    | .00968                   | 27.84                   | 103.27                     | .03592                    | 8.78                     | 70.68                     | 79.46                   | .0199                    | .1724                   | 4           |
| 6           | 1.011                   | 27.86*    | .00970                   | 26.27                   | 103.13                     | .03806                    | 9.19                     | 70.56                     | 79.75                   | .0208                    | .1723                   | 6           |
| 8           | 1.075                   | 27.73*    | .00971                   | 24.81                   | 102.98                     | .04031                    | 9.59                     | 70.44                     | 80.03                   | .0216                    | .1723                   | 8           |
| 10          | 1.142                   | 27.60*    | 0.00972                  | 23.45                   | 102.84                     | 0.04265                   | 10.00                    | 70.32                     | 80.32                   | 0.0225                   | 0.1723                  | 10          |
| 12          | 1.213                   | 27.45*    | .00974                   | 22.17                   | 102.69                     | .04511                    | 10.41                    | 70.20                     | 80.61                   | .0234                    | .1722                   | 12          |
| 14          | 1.288                   | 27.30*    | .00975                   | 20.97                   | 102.55                     | .04769                    | 10.81                    | 70.08                     | 80.89                   | .0242                    | .1722                   | 14          |
| 16          | 1.366                   | 27.14*    | .00977                   | 19.84                   | 102.40                     | .05040                    | 11.22                    | 69.96                     | 81.18                   | .0251                    | .1722                   | 16          |
| 18          | 1.448                   | 26.97*    | .00978                   | 18.79                   | 102.25                     | .05322                    | 11.62                    | 69.84                     | 81.46                   | .0259                    | .1722                   | 18          |
| 20          | 1.534                   | 26.80*    | 0.00979                  | 17.81                   | 102.10                     | 0.05616                   | 12.03                    | 69.72                     | 81.75                   | 0.0268                   | 0.1722                  | 20          |
| 22          | 1.624                   | 26.61*    | .00981                   | 16.89                   | 101.96                     | .05922                    | 12.44                    | 69.60                     | 82.04                   | .0276                    | .1721                   | 22          |
| 24          | 1.719                   | 26.42*    | .00982                   | 16.02                   | 101.81                     | .06243                    | 12.85                    | 69.48                     | 82.33                   | .0285                    | .1721                   | 24          |
| 26          | 1.818                   | 26.22*    | .00984                   | 15.20                   | 101.66                     | .06579                    | 13.26                    | 69.36                     | 82.62                   | .0293                    | .1722                   | 26          |
| 28          | 1.922                   | 26.01*    | .00985                   | 14.43                   | 101.51                     | .06929                    | 13.67                    | 69.24                     | 82.91                   | .0302                    | .1722                   | 28          |
| 30          | 2.031                   | 25.79*    | 0.00987                  | 13.71                   | 101.36                     | 0.07294                   | 14.08                    | 69.12                     | 83.20                   | 0.0310                   | 0.1722                  | 30          |
| 32          | 2.145                   | 25.55*    | .00988                   | 13.03                   | 101.21                     | .07675                    | 14.49                    | 69.00                     | 83.49                   | .0318                    | .1722                   | 32          |
| 34          | 2.264                   | 25.31*    | .00990                   | 12.39                   | 101.06                     | .08071                    | 14.91                    | 68.87                     | 83.78                   | .0327                    | .1722                   | 34          |
| 36          | 2.388                   | 25.06*    | .00991                   | 11.79                   | 100.91                     | .08483                    | 15.32                    | 68.75                     | 84.07                   | .0335                    | .1722                   | 36          |
| 38          | 2.519                   | 24.79*    | .00993                   | 11.22                   | 100.76                     | .08913                    | 15.74                    | 68.62                     | 84.36                   | .0343                    | .1722                   | 38          |
| 40          | 2.655                   | 24.52*    | 0.00994                  | 10.68                   | 100.60                     | .09361                    | 16.16                    | 68.50                     | 84.65                   | 0.0352                   | 0.1723                  | 40          |
| 42          | 2.797                   | 24.23*    | .00996                   | 10.18                   | 100.45                     | .09826                    | 16.57                    | 68.37                     | 84.94                   | .0360                    | .1723                   | 42          |
| 44          | 2.944                   | 23.93*    | .00997                   | 9.703                   | 100.30                     | .1031                     | 16.99                    | 68.25                     | 85.24                   | .0368                    | .1723                   | 44          |
| 46          | 3.098                   | 23.61*    | .00999                   | 9.253                   | 100.14                     | .1081                     | 17.41                    | 68.12                     | 85.53                   | .0377                    | .1724                   | 46          |
| 48          | 3.258                   | 23.29*    | .01000                   | 8.830                   | 99.99                      | .1133                     | 17.82                    | 68.00                     | 85.82                   | .0385                    | .1724                   | 48          |
| 50          | 3.427                   | 22.94*    | 0.01002                  | 8.426                   | 99.83                      | 0.1187                    | 18.24                    | 67.87                     | 86.11                   | 0.0393                   | 0.1725                  | 50          |
| 52          | 3.602                   | 22.59*    | .01003                   | 8.044                   | 99.68                      | .1243                     | 18.66                    | 67.74                     | 86.40                   | .0401                    | .1726                   | 52          |
| 54          | 3.784                   | 22.22*    | .01005                   | 7.682                   | 99.52                      | .1302                     | 19.08                    | 67.61                     | 86.69                   | .0410                    | .1726                   | 54          |
| 56          | 3.973                   | 21.83*    | .01006                   | 7.342                   | 99.37                      | .1362                     | 19.50                    | 67.48                     | 86.98                   | .0418                    | .1727                   | 56          |
| 58          | 4.170                   | 21.43*    | .01008                   | 7.018                   | 99.21                      | .1425                     | 19.93                    | 67.35                     | 87.28                   | .0426                    | .1727                   | 58          |
| 60          | 4.374                   | 21.02*    | 0.01010                  | 6.713                   | 99.05                      | 0.1490                    | 20.35                    | 67.22                     | 87.57                   | 0.0434                   | 0.1728                  | 60          |
| 62          | 4.586                   | 20.59*    | .01011                   | 6.424                   | 98.89                      | .1557                     | 20.77                    | 67.09                     | 87.86                   | .0442                    | .1729                   | 62          |
| 64          | 4.807                   | 20.14*    | .01013                   | 6.149                   | 98.73                      | .1626                     | 21.19                    | 66.96                     | 88.15                   | .0450                    | .1729                   | 64          |
| 66          | 5.036                   | 19.67*    | .01015                   | 5.889                   | 98.58                      | .1698                     | 21.62                    | 66.83                     | 88.45                   | .0459                    | .1730                   | 66          |
| 68          | 5.275                   | 19.18*    | .01016                   | 5.640                   | 98.42                      | .1773                     | 22.05                    | 66.69                     | 88.74                   | .0467                    | .1731                   | 68          |
| 70          | 5.523                   | 18.68*    | 0.01018                  | 5.404                   | 98.26                      | 0.1851                    | 22.48                    | 66.56                     | 89.04                   | 0.0475                   | 0.1731                  | 70          |
| 72          | 5.780                   | 18.16*    | .01019                   | 5.180                   | 98.10                      | .1931                     | 22.90                    | 66.43                     | 89.33                   | .0483                    | .1732                   | 72          |
| 74          | 6.042                   | 17.62*    | .01021                   | 4.971                   | 97.93                      | .2012                     | 23.33                    | 66.29                     | 89.62                   | .0491                    | .1733                   | 74          |
| 76          | 6.320                   | 17.06*    | .01023                   | 4.769                   | 97.77                      | .2097                     | 23.76                    | 66.16                     | 89.92                   | .0499                    | .1734                   | 76          |
| 78          | 6.607                   | 16.47*    | .01025                   | 4.574                   | 97.61                      | .2186                     | 24.19                    | 66.02                     | 90.21                   | .0507                    | .1735                   | 78          |
| 80          | 6.902                   | 15.87*    | 0.01026                  | 4.392                   | 97.45                      | 0.2277                    | 24.63                    | 65.88                     | 90.51                   | 0.0515                   | 0.1736                  | 80          |
| 82          | 7.208                   | 15.25*    | .01028                   | 4.218                   | 97.28                      | .2371                     | 25.06                    | 65.74                     | 90.80                   | .0523                    | .1737                   | 82          |
| 84          | 7.527                   | 14.60*    | .01030                   | 4.051                   | 97.12                      | .2468                     | 25.49                    | 65.60                     | 91.09                   | .0531                    | .1738                   | 84          |
| 86          | 7.856                   | 13.93*    | .01031                   | 3.893                   | 96.96                      | .2569                     | 25.93                    | 65.46                     | 91.39                   | .0539                    | .1739                   | 86          |
| 88          | 8.194                   | 13.24*    | .01033                   | 3.742                   | 96.79                      | .2672                     | 26.36                    | 65.32                     | 91.68                   | .0547                    | .1740                   | 88          |
| 90          | 8.545                   | 12.53*    | 0.01035                  | 3.600                   | 96.63                      | 0.2778                    | 26.80                    | 65.18                     | 91.98                   | 0.0555                   | 0.1741                  | 90          |
| 92          | 8.908                   | 11.79*    | .01037                   | 3.463                   | 96.46                      | .2888                     | 27.24                    | 65.04                     | 92.28                   | .0563                    | .1742                   | 92          |
| 94          | 9.281                   | 11.03*    | .01039                   | 3.333                   | 96.30                      | .3001                     | 27.67                    | 64.90                     | 92.57                   | .0571                    | .1743                   | 94          |
| 96          | 9.668                   | 10.24*    | .01040                   | 3.208                   | 96.13                      | .3117                     | 28.11                    | 64.75                     | 92.86                   | .0578                    | .1744                   | 96          |
| 98          | 10.07                   | 9.42*     | .01042                   | 3.089                   | 95.96                      | .3237                     | 28.55                    | 64.60                     | 93.15                   | .0586                    | .1745                   | 98          |
| 100         | 10.48                   | 8.59*     | 0.01044                  | 2.976                   | 95.79                      | 0.3360                    | 28.99                    | 64.46                     | 93.45                   | 0.0594                   | 0.1746                  | 100         |
| 102         | 10.91                   | 7.71*     | .01046                   | 2.867                   | 95.63                      | .3488                     | 29.44                    | 64.31                     | 93.75                   | .0602                    | .1747                   | 102         |
| 104         | 11.35                   | 6.82*     | .01048                   | 2.762                   | 95.46                      | .3620                     | 29.89                    | 64.16                     | 94.05                   | .0610                    | .1748                   | 104         |
| 106         | 11.81                   | 5.88*     | .01050                   | 2.662                   | 95.29                      | .3756                     | 30.33                    | 64.01                     | 94.34                   | .0618                    | .1750                   | 106         |
| 108         | 12.28                   | 4.93*     | .01051                   | 2.567                   | 95.12                      | .3896                     | 30.78                    | 63.86                     | 94.64                   | .0626                    | .1751                   | 108         |

\*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours &amp; Co.



TABLE 6-PROPERTIES OF REFRIGERANT 113, LIQUID AND SATURATED VAPOR (Contd)

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| 110         | 12.76                   | 3.95*     | 0.01053                  | 2.477                   | 94.95                      | 0.4038                    | 31.22                    | 63.71                     | 94.93                   | 0.0634                   | 0.1752                  | 110         |
| 112         | 13.25                   | 2.95*     | .01055                   | 2.391                   | 94.78                      | .4182                     | 31.67                    | 63.56                     | 95.23                   | .0641                    | .1753                   | 112         |
| 114         | 13.76                   | 1.91*     | .01057                   | 2.308                   | 94.61                      | .4333                     | 32.12                    | 63.40                     | 95.52                   | .0649                    | .1755                   | 114         |
| 116         | 14.29                   | 0.83*     | .01059                   | 2.228                   | 94.43                      | .4489                     | 32.57                    | 63.25                     | 95.82                   | .0657                    | .1756                   | 116         |
| 118         | 14.84                   | 0.14      | .01061                   | 2.151                   | 94.26                      | .4649                     | 33.03                    | 63.09                     | 96.12                   | .0665                    | .1757                   | 118         |
| 120         | 15.40                   | 0.70      | 0.01063                  | 2.078                   | 94.09                      | 0.4813                    | 33.48                    | 62.93                     | 96.41                   | 0.0673                   | 0.1758                  | 120         |
| 122         | 15.97                   | 1.27      | .01065                   | 2.008                   | 93.92                      | .4981                     | 33.93                    | 62.78                     | 96.71                   | .0680                    | .1760                   | 122         |
| 124         | 16.56                   | 1.86      | .01067                   | 1.941                   | 93.74                      | .5153                     | 34.38                    | 62.62                     | 97.00                   | .0688                    | .1761                   | 124         |
| 126         | 17.17                   | 2.47      | .01069                   | 1.876                   | 93.57                      | .5330                     | 34.83                    | 62.46                     | 97.29                   | .0696                    | .1763                   | 126         |
| 128         | 17.80                   | 3.10      | .01071                   | 1.814                   | 93.39                      | .5514                     | 35.29                    | 62.30                     | 97.59                   | .0704                    | .1764                   | 128         |
| 130         | 18.45                   | 3.74      | 0.01073                  | 1.754                   | 93.22                      | 0.5702                    | 35.75                    | 62.14                     | 97.89                   | 0.0712                   | 0.1765                  | 130         |
| 132         | 19.11                   | 4.41      | .01075                   | 1.697                   | 93.04                      | .5894                     | 36.21                    | 61.97                     | 98.18                   | .0719                    | .1767                   | 132         |
| 134         | 19.79                   | 5.09      | .01077                   | 1.642                   | 92.86                      | .6091                     | 36.67                    | 61.80                     | 98.47                   | .0727                    | .1768                   | 134         |
| 136         | 20.48                   | 5.78      | .01079                   | 1.590                   | 92.69                      | .6290                     | 37.13                    | 61.64                     | 98.77                   | .0735                    | .1770                   | 136         |
| 138         | 21.19                   | 6.49      | .01081                   | 1.540                   | 92.51                      | .6494                     | 37.59                    | 61.48                     | 99.06                   | .0742                    | .1771                   | 138         |
| 140         | 21.93                   | 7.23      | 0.01083                  | 1.491                   | 92.33                      | 0.6707                    | 38.05                    | 61.31                     | 99.36                   | 0.0750                   | 0.1773                  | 140         |
| 142         | 22.69                   | 7.99      | .01085                   | 1.444                   | 92.15                      | .6926                     | 38.52                    | 61.13                     | 99.65                   | .0758                    | .1774                   | 142         |
| 144         | 23.47                   | 8.77      | .01087                   | 1.399                   | 91.98                      | .7150                     | 38.98                    | 60.96                     | 99.94                   | .0765                    | .1775                   | 144         |
| 146         | 24.27                   | 9.57      | .01089                   | 1.355                   | 91.80                      | .7379                     | 39.45                    | 60.79                     | 100.24                  | .0773                    | .1777                   | 146         |
| 148         | 25.09                   | 10.39     | .01092                   | 1.313                   | 91.62                      | .7615                     | 39.92                    | 60.61                     | 100.53                  | .0781                    | .1778                   | 148         |
| 150         | 25.93                   | 11.23     | 0.01094                  | 1.273                   | 91.44                      | 0.7856                    | 40.38                    | 60.44                     | 100.82                  | 0.0789                   | 0.1780                  | 150         |
| 152         | 26.79                   | 12.09     | .01096                   | 1.234                   | 91.25                      | .8102                     | 40.85                    | 60.27                     | 101.11                  | .0796                    | .1782                   | 152         |
| 154         | 27.67                   | 12.97     | .01098                   | 1.197                   | 91.07                      | .8353                     | 41.32                    | 60.09                     | 101.41                  | .0804                    | .1783                   | 154         |
| 156         | 28.56                   | 13.86     | .01100                   | 1.162                   | 90.89                      | .8608                     | 41.79                    | 59.91                     | 101.70                  | .0812                    | .1785                   | 156         |
| 158         | 29.48                   | 14.78     | .01102                   | 1.128                   | 90.71                      | .8869                     | 42.26                    | 59.73                     | 101.99                  | .0819                    | .1786                   | 158         |
| 160         | 30.44                   | 15.74     | 0.01105                  | 1.094                   | 90.53                      | 0.9141                    | 42.74                    | 59.55                     | 102.29                  | 0.0827                   | 0.1788                  | 160         |

TABLE 7-PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
| t           | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> | t           |
| -80         | 0.464                   | 28.97*    | 0.009469                 | 51.26                   | 105.603                    | 0.01951                   | - 8.73                   | 69.17                     | 60.44                   | - 0.0227                 | 0.1595                  | -80         |
| -78         | 0.50                    | 28.90*    | .009484                  | 49.83                   | 105.398                    | .02007                    | - 8.30                   | 69.01                     | 60.71                   | - .0215                  | .1593                   | -78         |
| -76         | 0.535                   | 28.85*    | .009506                  | 44.87                   | 105.193                    | .02229                    | - 7.87                   | 68.85                     | 60.98                   | - .0203                  | .1592                   | -76         |
| -74         | 0.58                    | 28.73*    | .009513                  | 41.69                   | 105.058                    | .0240                     | - 7.44                   | 68.69                     | 61.25                   | - .0191                  | .1590                   | -74         |
| -72         | 0.62                    | 28.66*    | .009528                  | 38.92                   | 104.924                    | .0257                     | - 7.01                   | 68.53                     | 61.52                   | - .0179                  | .1589                   | -72         |
| -70         | 0.670                   | 28.59*    | 0.009543                 | 36.40                   | 104.790                    | 0.02747                   | - 6.57                   | 68.36                     | 61.79                   | - 0.0167                 | 0.1587                  | -70         |
| -68         | 0.72                    | 28.46*    | .009558                  | 34.20                   | 104.624                    | .02925                    | - 6.14                   | 68.20                     | 62.06                   | - .0155                  | .1586                   | -68         |
| -66         | 0.775                   | 28.33*    | .009573                  | 31.74                   | 104.458                    | .0315                     | - 5.71                   | 68.04                     | 62.33                   | - .0143                  | .1585                   | -66         |
| -64         | 0.833                   | 28.23*    | .009589                  | 29.77                   | 104.292                    | .0336                     | - 5.28                   | 67.88                     | 62.60                   | - .0132                  | .1583                   | -64         |
| -62         | 0.895                   | 28.10*    | .009604                  | 27.79                   | 104.126                    | .0360                     | - 4.84                   | 67.72                     | 62.88                   | - .0121                  | .1582                   | -62         |
| -60         | 0.959                   | 27.99*    | 0.009619                 | 26.06                   | 103.960                    | 0.03838                   | - 4.40                   | 67.56                     | 63.16                   | - 0.0110                 | 0.1580                  | -60         |
| -58         | 1.028                   | 27.83*    | .009635                  | 24.55                   | 103.792                    | .04075                    | - 3.96                   | 67.39                     | 63.43                   | - .0098                  | .1579                   | -58         |
| -56         | 1.10                    | 27.68*    | .009651                  | 22.94                   | 103.622                    | .0436                     | - 3.52                   | 67.22                     | 63.70                   | - .0087                  | .1578                   | -56         |
| -54         | 1.175                   | 27.52*    | .009666                  | 21.50                   | 103.452                    | .0465                     | - 3.08                   | 67.05                     | 63.97                   | - .0075                  | .1577                   | -54         |
| -52         | 1.26                    | 27.35*    | .009682                  | 20.16                   | 103.282                    | .0496                     | - 2.64                   | 66.89                     | 64.25                   | - .0064                  | .1576                   | -52         |
| -50         | 1.349                   | 27.20*    | 0.009698                 | 18.96                   | 103.113                    | 0.05274                   | - 2.20                   | 66.73                     | 64.53                   | - 0.0054                 | 0.1575                  | -50         |
| -48         | 1.438                   | 27.0 *    | .009714                  | 17.85                   | 102.938                    | .0560                     | - 1.76                   | 66.56                     | 64.80                   | - .0043                  | .1574                   | -48         |
| -46         | 1.535                   | 26.8 *    | .009731                  | 16.80                   | 102.766                    | .0595                     | - 1.32                   | 66.39                     | 65.07                   | - .0032                  | .1573                   | -46         |
| -44         | 1.635                   | 26.6 *    | .009747                  | 15.75                   | 102.594                    | .0635                     | - 0.88                   | 66.23                     | 65.35                   | - .0021                  | .1572                   | -44         |
| -42         | 1.745                   | 26.4 *    | .009764                  | 14.87                   | 102.422                    | .06725                    | - 0.44                   | 66.07                     | 65.63                   | - .0010                  | .1571                   | -42         |
| -40         | 1.866                   | 26.12*    | 0.00978                  | 14.02                   | 102.25                     | 0.07132                   | 0.00                     | 65.91                     | 65.91                   | 0.0000                   | 0.1571                  | -40         |
| -38         | 1.990                   | 25.87*    | .00980                   | 13.20                   | 102.08                     | .07574                    | 0.45                     | 65.74                     | 66.19                   | .0011                    | .1570                   | -38         |
| -36         | 2.121                   | 25.60*    | .00981                   | 12.44                   | 101.90                     | .08038                    | 0.91                     | 65.56                     | 66.47                   | .0021                    | .1569                   | -36         |
| -34         | 2.259                   | 25.32*    | .00983                   | 11.73                   | 101.72                     | .08524                    | 1.36                     | 65.38                     | 66.74                   | .0032                    | .1568                   | -34         |
| -32         | 2.404                   | 25.03*    | .00985                   | 11.07                   | 101.55                     | .09034                    | 1.81                     | 65.21                     | 67.02                   | .0042                    | .1567                   | -32         |
| -30         | 2.557                   | 24.72*    | 0.00987                  | 10.45                   | 101.37                     | 0.09568                   | 2.27                     | 65.03                     | 67.30                   | 0.0053                   | 0.1567                  | -30         |
| -28         | 2.718                   | 24.39*    | .00988                   | 9.877                   | 101.19                     | .1013                     | 2.72                     | 64.86                     | 67.58                   | .0063                    | .1567                   | -28         |
| -26         | 2.887                   | 24.04*    | .00990                   | 9.338                   | 101.01                     | .1071                     | 3.17                     | 64.68                     | 67.86                   | .0074                    | .1566                   | -26         |
| -24         | 3.064                   | 23.68*    | .00992                   | 8.833                   | 100.83                     | .1132                     | 3.63                     | 64.51                     | 68.14                   | .0084                    | .1565                   | -24         |
| -22         | 3.249                   | 23.31*    | .00994                   | 8.362                   | 100.65                     | .1196                     | 4.08                     | 64.34                     | 68.42                   | .0095                    | .1565                   | -22         |
| -20         | 3.444                   | 22.91*    | 0.00995                  | 7.921                   | 100.47                     | 0.1263                    | 4.54                     | 64.16                     | 68.70                   | 0.0105                   | 0.1565                  | -20         |
| -18         | 3.648                   | 22.49*    | .00997                   | 7.508                   | 100.29                     | .1332                     | 4.99                     | 63.99                     | 68.98                   | .0116                    | .1565                   | -18         |
| -16         | 3.862                   | 22.06*    | .00999                   | 7.121                   | 100.11                     | .1404                     | 5.44                     | 63.81                     | 69.26                   | .0126                    | .1564                   | -16         |
| -14         | 4.085                   | 21.61*    | .01001                   | 6.757                   | 99.92                      | .1480                     | 5.90                     | 63.64                     | 69.54                   | .0136                    | .1564                   | -14         |
| -12         | 4.319                   | 21.13*    | .01003                   | 6.416                   | 99.74                      | .1559                     | 6.35                     | 63.46                     | 69.82                   | .0146                    | .1564                   | -12         |
| -10         | 4.564                   | 20.63*    | 0.01005                  | 6.095                   | 99.56                      | 0.1641                    | 6.81                     | 63.29                     | 70.10                   | 0.0157                   | 0.1564                  | -10         |
| -8          | 4.819                   | 20.11*    | .01006                   | 5.794                   | 99.37                      | .1726                     | 7.26                     | 63.11                     | 70.38                   | .0167                    | .1564                   | -8          |
| -6          | 5.086                   | 19.57*    | .01008                   | 5.510                   | 99.19                      | .1815                     | 7.72                     | 62.94                     | 70.66                   | .0177                    | .1564                   | -6          |
| -4          | 5.365                   | 19.00*    | .01010                   | 5.244                   | 99.00                      | .1907                     | 8.18                     | 62.77                     | 70.94                   | .0187                    | .1564                   | -4          |
| -2          | 5.655                   | 18.41*    | .01012                   | 4.992                   | 98.81                      | .2003                     | 8.63                     | 62.59                     | 71.22                   | .0197                    | .1565                   | -2          |
| 0           | 5.958                   | 17.79*    | 0.01014                  | 4.756                   | 98.62                      | 0.2103                    | 9.09                     | 62.42                     | 71.50                   | 0.0207                   | 0.1565                  | 0           |
| 2           | 6.274                   | 17.15*    | .01016                   | 4.533                   | 98.44                      | .2206                     | 9.54                     | 62.24                     | 71.78                   | .0217                    | .1565                   | 2           |
| 4           | 6.603                   | 16.48*    | .01018                   | 4.322                   | 98.25                      | .2314                     | 10.00                    | 62.07                     | 72.07                   | .0227                    | .1565                   | 4           |
| 6           | 6.945                   | 15.78*    | .01020                   | 4.123                   | 98.06                      | .2425                     | 10.46                    | 61.89                     | 72.35                   | .0236                    | .1566                   | 6           |
| 8           | 7.301                   | 15.06*    | .01022                   | 3.935                   | 97.87                      | .2541                     | 10.91                    | 61.71                     | 72.63                   | .0246                    | .1566                   | 8           |
| 10          | 7.671                   | 14.31*    | 0.01024                  | 3.758                   | 97.68                      | 0.2661                    | 11.37                    | 61.54                     | 72.91                   | 0.0256                   | 0.1566                  | 10          |
| 12          | 8.057                   | 13.52*    | .01026                   | 3.591                   | 97.48                      | .2785                     | 11.83                    | 61.36                     | 73.19                   | .0266                    | .1567                   | 12          |
| 14          | 8.457                   | 12.71*    | .01028                   | 3.432                   | 97.29                      | .2914                     | 12.29                    | 61.19                     | 73.47                   | .0275                    | .1567                   | 14          |
| 16          | 8.873                   | 11.86*    | .01030                   | 3.282                   | 97.10                      | .3047                     | 12.75                    | 61.01                     | 73.75                   | .0285                    | .1568                   | 16          |
| 18          | 9.305                   | 10.98*    | .01032                   | 3.140                   | 96.90                      | .3185                     | 13.20                    | 60.83                     | 74.04                   | .0295                    | .1568                   | 18          |
| 20          | 9.753                   | 10.07*    | 0.01034                  | 3.005                   | 96.71                      | 0.3328                    | 13.66                    | 60.65                     | 74.32                   | 0.0304                   | 0.1569                  | 20          |
| 22          | 10.22                   | 9.12*     | .01036                   | 2.877                   | 96.51                      | .3476                     | 14.12                    | 60.48                     | 74.60                   | .0314                    | .1569                   | 22          |
| 24          | 10.70                   | 8.14*     | .01038                   | 2.756                   | 96.32                      | .3629                     | 14.58                    | 60.30                     | 74.88                   | .0323                    | .1570                   | 24          |
| 26          | 11.20                   | 7.12*     | .01040                   | 2.641                   | 96.12                      | .3786                     | 15.05                    | 60.12                     | 75.17                   | .0333                    | .1571                   | 26          |
| 28          | 11.72                   | 6.07*     | .01043                   | 2.532                   | 95.92                      | .3949                     | 15.51                    | 59.94                     | 75.45                   | .0342                    | .1571                   | 28          |
| 30          | 12.25                   | 4.99*     | 0.01045                  | 2.429                   | 95.73                      | 0.4118                    | 15.97                    | 59.76                     | 75.73                   | 0.0352                   | 0.1572                  | 30          |
| 32          | 12.81                   | 3.85*     | .01047                   | 2.330                   | 95.53                      | .4292                     | 16.43                    | 59.58                     | 76.01                   | .0361                    | .1573                   | 32          |
| 34          | 13.38                   | 2.69*     | .01049                   | 2.236                   | 95.33                      | .4472                     | 16.89                    | 59.40                     | 76.29                   | .0370                    | .1574                   | 34          |
| 36          | 13.98                   | 1.47*     | .01051                   | 2.147                   | 95.13                      | .4658                     | 17.36                    | 59.22                     | 76.58                   | .0380                    | .1575                   | 36          |
| 38          | 14.59                   | 0.22*     | .01053                   | 2.062                   | 94.93                      | .4849                     | 17.82                    | 59.04                     | 76.86                   | .0389                    | .1575                   | 38          |
| 40          | 15.22                   | 0.52      | 0.01056                  | 1.982                   | 94.73                      | 0.5047                    | 18.28                    | 58.86                     | 77.14                   | 0.0398                   | 0.1576                  | 40          |
| 42          | 15.88                   | 1.18      | .01058                   | 1.905                   | 94.52                      | .5250                     | 18.75                    | 58.67                     | 77.42                   | .0408                    | .1577                   | 42          |
| 44          | 16.56                   | 1.86      | .01060                   | 1.832                   | 94.32                      | .5460                     | 19.21                    | 58.49                     | 77.70                   | .0417                    | .1578                   | 44          |
| 46          | 17.26                   | 2.56      | .01063                   | 1.762                   | 94.12                      | .5676                     | 19.68                    | 58.31                     | 77.99                   | .0426                    | .1579                   | 46          |
| 48          | 17.98                   | 3.28      | .01065                   | 1.695                   | 93.91                      | .5899                     | 20.14                    | 58.12                     | 78.27                   | .0435                    | .1580                   | 48          |
| 50          | 18.73                   | 4.03      | 0.01067                  | 1.632                   | 93.71                      | 0.6129                    | 20.61                    | 57.94                     | 78.55                   | 0.0444                   | 0.1581                  | 50          |
| 52          | 19.50                   | 4.80      | .01070                   | 1.571                   | 93.50                      | .6365                     | 21.08                    | 57.75                     | 78.83                   | .0453                    | .1582                   | 52          |
| 54          | 20.29                   | 5.59      | .01072                   | 1.513                   | 93.30                      | .6609                     | 21.54                    | 57.56                     | 79.11                   | .0463                    | .1583                   | 54          |
| 56          | 21.11                   | 6.41      | .01074                   | 1.458                   | 93.09                      | .6859                     | 22.01                    | 57.38                     | 79.39                   | .0472                    | .1584                   | 56          |
| 58          | 21.96                   | 7.26      | .01077                   | 1.405                   | 92.88                      | .7117                     | 22.48                    | 57.19                     | 79.67                   | .0481                    | .1585                   | 58          |

\*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours &amp; Co.



**TABLE 7—PROPERTIES OF REFRIGERANT 114, LIQUID AND SATURATED VAPOR (Contd)**

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| 60          | 22.83                   | 8.13      | 0.01079                  | 1.354                   | 92.68                      | 0.7383                    | 22.95                    | 57.00                     | 79.95                   | 0.0490                   | 0.1587                  | 60          |
| 62          | 23.72                   | 9.02      | .01082                   | 1.306                   | 92.47                      | .7655                     | 23.42                    | 56.81                     | 80.23                   | .0499                    | .1588                   | 62          |
| 64          | 24.64                   | 9.94      | .01084                   | 1.260                   | 92.26                      | .7936                     | 23.89                    | 56.62                     | 80.51                   | .0508                    | .1589                   | 64          |
| 66          | 25.59                   | 10.89     | .01086                   | 1.216                   | 92.05                      | .8225                     | 24.36                    | 56.43                     | 80.79                   | .0517                    | .1590                   | 66          |
| 68          | 26.57                   | 11.87     | .01089                   | 1.174                   | 91.84                      | .8521                     | 24.83                    | 56.24                     | 81.07                   | .0526                    | .1591                   | 68          |
| 70          | 27.57                   | 12.87     | 0.01091                  | 1.133                   | 91.63                      | 0.8826                    | 25.30                    | 56.04                     | 81.35                   | 0.0534                   | 0.1593                  | 70          |
| 72          | 28.61                   | 13.91     | .01094                   | 1.094                   | 91.41                      | 0.9140                    | 25.78                    | 55.85                     | 81.62                   | .0543                    | .1594                   | 72          |
| 74          | 29.67                   | 14.97     | .01097                   | 1.057                   | 91.20                      | 0.9462                    | 26.25                    | 55.65                     | 81.90                   | .0552                    | .1595                   | 74          |
| 76          | 30.76                   | 16.06     | .01099                   | 1.021                   | 90.99                      | 0.9793                    | 26.73                    | 55.45                     | 82.18                   | .0561                    | .1596                   | 76          |
| 78          | 31.88                   | 17.18     | .01102                   | 0.9869                  | 90.77                      | 1.013                     | 27.20                    | 55.26                     | 82.46                   | .0570                    | .1597                   | 78          |
| 80          | 33.04                   | 18.34     | 0.01104                  | 0.9541                  | 90.56                      | 1.048                     | 27.68                    | 55.06                     | 82.73                   | 0.0579                   | 0.1599                  | 80          |
| 82          | 34.22                   | 19.52     | .01107                   | .9226                   | 90.34                      | 1.084                     | 28.15                    | 54.86                     | 83.01                   | .0587                    | .1600                   | 82          |
| 84          | 35.44                   | 20.74     | .01110                   | .8923                   | 90.13                      | 1.121                     | 28.63                    | 54.66                     | 83.29                   | .0596                    | .1601                   | 84          |
| 86          | 36.69                   | 21.99     | .01112                   | .8632                   | 89.91                      | 1.159                     | 29.11                    | 54.46                     | 83.56                   | .0605                    | .1603                   | 86          |
| 88          | 37.97                   | 23.27     | .01115                   | .8353                   | 89.69                      | 1.197                     | 29.58                    | 54.25                     | 83.84                   | .0613                    | .1604                   | 88          |
| 90          | 39.29                   | 24.59     | 0.01118                  | 0.8084                  | 89.47                      | 1.237                     | 30.06                    | 54.05                     | 84.11                   | 0.0622                   | 0.1605                  | 90          |
| 92          | 40.64                   | 25.94     | .01120                   | .7827                   | 89.25                      | 1.278                     | 30.54                    | 53.84                     | 84.39                   | .0631                    | .1607                   | 92          |
| 94          | 42.02                   | 27.32     | .01123                   | .7579                   | 89.03                      | 1.320                     | 31.02                    | 53.64                     | 84.66                   | .0639                    | .1608                   | 94          |
| 96          | 43.44                   | 28.74     | .01126                   | .7340                   | 88.81                      | 1.362                     | 31.50                    | 53.43                     | 84.93                   | .0648                    | .1609                   | 96          |
| 98          | 44.89                   | 30.19     | .01129                   | .7111                   | 88.59                      | 1.406                     | 31.99                    | 53.22                     | 85.21                   | .0656                    | .1611                   | 98          |
| 100         | 46.39                   | 31.69     | 0.01132                  | 0.6890                  | 88.37                      | 1.452                     | 32.47                    | 53.01                     | 85.48                   | 0.0665                   | 0.1612                  | 100         |
| 102         | 47.92                   | 33.22     | .01135                   | .6677                   | 88.15                      | 1.498                     | 32.95                    | 52.80                     | 85.75                   | .0674                    | .1614                   | 102         |
| 104         | 49.48                   | 34.78     | .01137                   | .6472                   | 87.93                      | 1.545                     | 33.43                    | 52.59                     | 86.02                   | .0682                    | .1615                   | 104         |
| 106         | 51.09                   | 36.39     | .01140                   | .6274                   | 87.70                      | 1.594                     | 33.92                    | 52.37                     | 86.29                   | .0691                    | .1617                   | 106         |
| 108         | 52.73                   | 38.03     | .01143                   | .6084                   | 87.48                      | 1.644                     | 34.40                    | 52.16                     | 86.56                   | .0699                    | .1618                   | 108         |
| 110         | 54.41                   | 39.71     | 0.01146                  | 0.5901                  | 87.25                      | 1.695                     | 34.89                    | 51.94                     | 86.83                   | 0.0708                   | 0.1619                  | 110         |
| 112         | 56.14                   | 41.44     | .01149                   | .5724                   | 87.01                      | 1.747                     | 35.38                    | 51.72                     | 87.09                   | .0716                    | .1621                   | 112         |
| 114         | 57.90                   | 43.20     | .01152                   | .5554                   | 86.77                      | 1.801                     | 35.87                    | 51.50                     | 87.36                   | .0725                    | .1622                   | 114         |
| 116         | 59.70                   | 45.00     | .01156                   | .5389                   | 86.54                      | 1.856                     | 36.35                    | 51.28                     | 87.63                   | .0733                    | .1624                   | 116         |
| 118         | 61.55                   | 46.85     | .01159                   | .5230                   | 86.31                      | 1.912                     | 36.84                    | 51.05                     | 87.89                   | .0741                    | .1625                   | 118         |
| 120         | 63.44                   | 48.74     | 0.01162                  | 0.5077                  | 86.08                      | 1.970                     | 37.33                    | 50.83                     | 88.16                   | 0.0750                   | 0.1627                  | 120         |
| 122         | 65.37                   | 50.67     | .01165                   | .4929                   | 85.85                      | 2.029                     | 37.83                    | 50.60                     | 88.42                   | .0758                    | .1628                   | 122         |
| 124         | 67.35                   | 52.65     | .01168                   | .4787                   | 85.61                      | 2.089                     | 38.32                    | 50.37                     | 88.69                   | .0767                    | .1630                   | 124         |
| 126         | 69.37                   | 54.67     | .01171                   | .4649                   | 85.37                      | 2.151                     | 38.81                    | 50.14                     | 88.95                   | .0775                    | .1631                   | 126         |
| 128         | 71.43                   | 56.73     | .01175                   | .4515                   | 85.13                      | 2.215                     | 39.31                    | 49.91                     | 89.21                   | .0783                    | .1633                   | 128         |
| 130         | 73.54                   | 58.84     | 0.01178                  | 0.4387                  | 84.89                      | 2.280                     | 39.80                    | 49.67                     | 89.47                   | 0.0792                   | 0.1634                  | 130         |
| 132         | 75.69                   | 60.99     | .01181                   | .4262                   | 84.65                      | 2.346                     | 40.30                    | 49.44                     | 89.73                   | .0800                    | .1635                   | 132         |
| 134         | 77.90                   | 63.20     | .01185                   | .4142                   | 84.41                      | 2.414                     | 40.80                    | 49.20                     | 89.99                   | .0808                    | .1637                   | 134         |
| 136         | 80.15                   | 65.45     | .01188                   | .4025                   | 84.16                      | 2.484                     | 41.29                    | 48.96                     | 90.25                   | .0816                    | .1638                   | 136         |
| 138         | 82.44                   | 67.74     | .01192                   | .3912                   | 83.91                      | 2.556                     | 41.79                    | 48.72                     | 90.51                   | .0825                    | .1640                   | 138         |
| 140         | 84.79                   | 70.09     | 0.01195                  | 0.3803                  | 83.66                      | 2.629                     | 42.29                    | 48.47                     | 90.76                   | 0.0833                   | 0.1641                  | 140         |



TABLE 8—PROPERTIES OF REFRIGERANT 502, LIQUID AND SATURATED VAPOR

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>f</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>f</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>f</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>f</sub> | Vapor<br>s <sub>g</sub> |             |
| —100        | 3.230                   | 23.34*    | 0.01015                  | 10.84                   | 98.49                      | 0.09228                   | —15.15                   | 82.52                     | 67.37                   | —0.0388                  | 0.1906                  | —100        |
| —98         | 3.466                   | 22.86*    | .01017                   | 10.15                   | 98.30                      | 0.09852                   | —14.65                   | 82.28                     | 67.63                   | —0.0375                  | .1900                   | —98         |
| —96         | 3.716                   | 22.36*    | .01019                   | 9.515                   | 98.11                      | 0.1051                    | —14.15                   | 82.04                     | 67.89                   | —0.0361                  | .1895                   | —96         |
| —94         | 3.979                   | 21.82*    | .01021                   | 8.928                   | 97.92                      | 0.1120                    | —13.66                   | 81.81                     | 68.15                   | —0.0347                  | .1890                   | —94         |
| —92         | 4.258                   | 21.25*    | .01023                   | 8.384                   | 97.72                      | 0.1193                    | —13.16                   | 81.57                     | 68.41                   | —0.0334                  | .1885                   | —92         |
| —90         | 4.552                   | 20.65*    | 0.01025                  | 7.879                   | 97.53                      | 0.1269                    | —12.66                   | 81.33                     | 68.67                   | —0.0320                  | 0.1880                  | —90         |
| —88         | 4.862                   | 20.02*    | .01027                   | 7.411                   | 97.34                      | 0.1349                    | —12.16                   | 81.09                     | 68.93                   | —0.0307                  | .1875                   | —88         |
| —86         | 5.190                   | 19.35*    | .01029                   | 6.976                   | 97.14                      | 0.1433                    | —11.66                   | 80.85                     | 69.19                   | —0.0294                  | .1870                   | —86         |
| —84         | 5.534                   | 18.65*    | .01031                   | 6.572                   | 96.95                      | 0.1522                    | —11.17                   | 80.62                     | 69.45                   | —0.0280                  | .1866                   | —84         |
| —82         | 5.897                   | 17.91*    | .01034                   | 6.196                   | 96.75                      | 0.1614                    | —10.67                   | 80.38                     | 69.71                   | —0.0267                  | .1861                   | —82         |
| —80         | 6.278                   | 17.14*    | 0.01036                  | 5.845                   | 96.55                      | 0.1711                    | —10.17                   | 80.14                     | 69.97                   | —0.0254                  | 0.1857                  | —80         |
| —78         | 6.679                   | 16.32*    | .01038                   | 5.519                   | 96.35                      | 0.1812                    | —9.66                    | 79.90                     | 70.24                   | —0.0241                  | .1853                   | —78         |
| —76         | 7.100                   | 15.47*    | .01040                   | 5.214                   | 96.15                      | 0.1918                    | —9.16                    | 79.66                     | 70.50                   | —0.0228                  | .1848                   | —76         |
| —74         | 7.541                   | 14.57*    | .01042                   | 4.930                   | 95.95                      | 0.2028                    | —8.65                    | 79.41                     | 70.76                   | —0.0215                  | .1844                   | —74         |
| —72         | 8.004                   | 13.62*    | .01044                   | 4.664                   | 95.75                      | 0.2144                    | —8.15                    | 79.17                     | 71.02                   | —0.0202                  | .1841                   | —72         |
| —70         | 8.490                   | 12.63*    | 0.01047                  | 4.416                   | 95.55                      | 0.2265                    | —7.65                    | 78.93                     | 71.28                   | —0.0189                  | 0.1837                  | —70         |
| —68         | 8.999                   | 11.60*    | .01049                   | 4.183                   | 95.35                      | 0.2390                    | —7.14                    | 78.68                     | 71.54                   | —0.0176                  | .1833                   | —68         |
| —66         | 9.531                   | 10.52*    | .01051                   | 3.966                   | 95.14                      | 0.2522                    | —6.64                    | 78.44                     | 71.80                   | —0.0163                  | .1829                   | —66         |
| —64         | 10.09                   | 9.38*     | .01053                   | 3.762                   | 94.94                      | 0.2658                    | —6.13                    | 78.19                     | 72.06                   | —0.0150                  | .1826                   | —64         |
| —62         | 10.67                   | 8.20*     | .01056                   | 3.571                   | 94.73                      | 0.2801                    | —5.63                    | 77.95                     | 72.32                   | —0.0137                  | .1823                   | —62         |
| —60         | 11.28                   | 6.96*     | 0.01058                  | 3.391                   | 94.52                      | 0.2949                    | —5.12                    | 77.70                     | 72.58                   | —0.0125                  | 0.1819                  | —60         |
| —58         | 11.91                   | 5.67*     | .01060                   | 3.222                   | 94.32                      | 0.3103                    | —4.61                    | 77.45                     | 72.84                   | —0.0112                  | .1816                   | —58         |
| —56         | 12.58                   | 4.32*     | .01063                   | 3.064                   | 94.11                      | 0.3264                    | —4.10                    | 77.20                     | 73.10                   | —0.0099                  | .1813                   | —56         |
| —54         | 13.27                   | 2.91*     | .01065                   | 2.915                   | 93.90                      | 0.3430                    | —3.59                    | 76.95                     | 73.36                   | —0.0087                  | .1810                   | —54         |
| —52         | 13.99                   | 1.44*     | .01067                   | 2.775                   | 93.69                      | 0.3604                    | —3.08                    | 76.70                     | 73.62                   | —0.0074                  | .1807                   | —52         |
| —50         | 14.74                   | 0.04      | 0.01070                  | 2.643                   | 93.47                      | 0.3784                    | —2.57                    | 76.44                     | 73.87                   | —0.0062                  | 0.1804                  | —50         |
| —48         | 15.52                   | 0.82      | .01072                   | 2.519                   | 93.26                      | 0.3971                    | —2.06                    | 76.19                     | 74.13                   | —0.0049                  | .1801                   | —48         |
| —46         | 16.33                   | 1.64      | .01075                   | 2.401                   | 93.05                      | 0.4165                    | —1.55                    | 75.94                     | 74.39                   | —0.0037                  | .1799                   | —46         |
| —44         | 17.18                   | 2.48      | .01077                   | 2.291                   | 92.83                      | 0.4366                    | —1.03                    | 75.68                     | 74.65                   | —0.0025                  | .1796                   | —44         |
| —42         | 18.06                   | 3.36      | .01080                   | 2.186                   | 92.62                      | 0.4574                    | —0.52                    | 75.42                     | 74.90                   | —0.0012                  | .1793                   | —42         |
| —40         | 18.97                   | 4.28      | 0.01082                  | 2.087                   | 92.40                      | 0.4791                    | 0                        | 75.16                     | 75.16                   | 0                        | 0.1791                  | —40         |
| —38         | 19.92                   | 5.23      | .01085                   | 1.994                   | 92.18                      | 0.5015                    | 0.52                     | 74.90                     | 75.42                   | .0012                    | .1788                   | —38         |
| —36         | 20.91                   | 6.21      | .01087                   | 1.906                   | 91.96                      | 0.5247                    | 1.03                     | 74.64                     | 75.67                   | .0024                    | .1786                   | —36         |
| —34         | 21.93                   | 7.24      | .01090                   | 1.823                   | 91.74                      | 0.5487                    | 1.56                     | 74.33                     | 75.93                   | .0037                    | .1784                   | —34         |
| —32         | 23.00                   | 8.30      | .01093                   | 1.744                   | 91.52                      | 0.5735                    | 2.07                     | 74.11                     | 76.18                   | .0049                    | .1781                   | —32         |
| —30         | 24.10                   | 9.40      | 0.01095                  | 1.669                   | 91.30                      | 0.5993                    | 2.60                     | 73.84                     | 76.44                   | 0.0061                   | 0.1779                  | —30         |
| —28         | 25.24                   | 10.54     | .01098                   | 1.598                   | 91.08                      | 0.6259                    | 3.12                     | 73.57                     | 76.69                   | .0073                    | .1777                   | —28         |
| —26         | 26.42                   | 11.72     | .01101                   | 1.531                   | 90.85                      | 0.6534                    | 3.64                     | 73.30                     | 76.94                   | .0085                    | .1775                   | —26         |
| —24         | 27.64                   | 12.95     | .01103                   | 1.467                   | 90.63                      | 0.6818                    | 4.16                     | 73.03                     | 77.19                   | .0097                    | .1773                   | —24         |
| —22         | 28.91                   | 14.21     | .01106                   | 1.406                   | 90.40                      | 0.7112                    | 4.69                     | 72.75                     | 77.44                   | .0109                    | .1771                   | —22         |
| —20         | 30.22                   | 15.52     | 0.01109                  | 1.349                   | 90.18                      | 0.7415                    | 5.21                     | 72.48                     | 77.69                   | 0.0121                   | 0.1769                  | —20         |
| —18         | 31.57                   | 16.88     | .01112                   | 1.294                   | 89.95                      | 0.7729                    | 5.74                     | 72.20                     | 77.94                   | .0133                    | .1767                   | —18         |
| —16         | 32.97                   | 18.28     | .01115                   | 1.242                   | 89.72                      | 0.8052                    | 6.27                     | 71.92                     | 78.19                   | .0145                    | .1766                   | —16         |
| —14         | 34.42                   | 19.72     | .01117                   | 1.193                   | 89.49                      | 0.8386                    | 6.80                     | 71.64                     | 78.44                   | .0156                    | .1764                   | —14         |
| —12         | 35.91                   | 21.22     | .01120                   | 1.145                   | 89.26                      | 0.8731                    | 7.33                     | 71.36                     | 78.69                   | .0168                    | .1762                   | —12         |
| —10         | 37.46                   | 22.76     | 0.01123                  | 1.101                   | 89.02                      | 0.9086                    | 7.86                     | 71.07                     | 78.93                   | 0.0180                   | 0.1760                  | —10         |
| —8          | 39.05                   | 24.35     | .01126                   | 1.058                   | 88.79                      | 0.9453                    | 8.40                     | 70.78                     | 79.18                   | .0192                    | .1759                   | —8          |
| —6          | 40.69                   | 26.00     | .01129                   | 1.017                   | 88.55                      | 0.9831                    | 8.93                     | 70.49                     | 79.42                   | .0204                    | .1757                   | —6          |
| —4          | 42.39                   | 27.69     | .01132                   | 0.9784                  | 88.32                      | 1.022                     | 9.47                     | 70.20                     | 79.67                   | .0215                    | .1756                   | —4          |
| —2          | 44.14                   | 29.44     | .01135                   | 0.9414                  | 88.08                      | 1.062                     | 10.00                    | 69.91                     | 79.91                   | .0227                    | .1754                   | —2          |
| 0           | 45.94                   | 31.24     | 0.01138                  | 0.9061                  | 87.84                      | 1.104                     | 10.54                    | 69.61                     | 80.15                   | 0.0239                   | 0.1753                  | 0           |
| 2           | 47.79                   | 33.10     | .01142                   | 0.8724                  | 87.60                      | 1.146                     | 11.08                    | 69.31                     | 80.39                   | .0250                    | .1751                   | 2           |
| 4           | 49.71                   | 35.01     | .01145                   | 0.8402                  | 87.36                      | 1.190                     | 11.62                    | 69.01                     | 80.63                   | .0262                    | .1750                   | 4           |
| 6           | 51.68                   | 36.98     | .01148                   | 0.8094                  | 87.12                      | 1.235                     | 12.16                    | 68.70                     | 80.86                   | .0273                    | .1749                   | 6           |
| 8           | 53.70                   | 39.01     | .01151                   | 0.7800                  | 86.88                      | 1.282                     | 12.70                    | 68.40                     | 81.10                   | .0285                    | .1747                   | 8           |
| 10          | 55.79                   | 41.09     | 0.01154                  | 0.7519                  | 86.63                      | 1.330                     | 13.25                    | 68.08                     | 81.33                   | 0.0296                   | 0.1746                  | 10          |
| 12          | 57.94                   | 43.24     | .01158                   | 0.7250                  | 86.39                      | 1.379                     | 13.80                    | 67.77                     | 81.57                   | .0308                    | .1745                   | 12          |
| 14          | 60.14                   | 45.45     | .01161                   | 0.6992                  | 86.14                      | 1.430                     | 14.34                    | 67.46                     | 81.80                   | .0319                    | .1743                   | 14          |
| 16          | 62.41                   | 47.72     | .01164                   | 0.6746                  | 85.89                      | 1.482                     | 14.89                    | 67.14                     | 82.03                   | .0331                    | .1742                   | 16          |
| 18          | 64.75                   | 50.05     | .01168                   | 0.6510                  | 85.64                      | 1.536                     | 15.44                    | 66.82                     | 82.26                   | .0342                    | .1741                   | 18          |
| 20          | 67.14                   | 52.45     | 0.01171                  | 0.6283                  | 85.39                      | 1.592                     | 15.99                    | 66.50                     | 82.49                   | 0.0354                   | 0.1740                  | 20          |
| 22          | 69.61                   | 54.91     | .01175                   | 0.6066                  | 85.14                      | 1.649                     | 16.54                    | 66.17                     | 82.71                   | .0365                    | .1739                   | 22          |
| 24          | 72.13                   | 57.44     | .01178                   | 0.5858                  | 84.88                      | 1.707                     | 17.10                    | 65.84                     | 82.94                   | .0376                    | .1738                   | 24          |
| 26          | 74.73                   | 60.04     | .01182                   | 0.5659                  | 84.63                      | 1.767                     | 17.65                    | 65.51                     | 83.16                   | .0388                    | .1736                   | 26          |
| 28          | 77.40                   | 62.70     | .01185                   | 0.5467                  | 84.37                      | 1.829                     | 18.21                    | 65.17                     | 83.38                   | .0399                    | .1735                   | 28          |
| 30          | 80.13                   | 65.44     | 0.01189                  | 0.5283                  | 84.11                      | 1.893                     | 18.76                    | 64.84                     | 83.60                   | 0.0410                   | 0.1734                  | 30          |
| 32          | 82.94                   | 68.24     | .01193                   | 0.5106                  | 83.85                      | 1.958                     | 19.32                    | 64.49                     | 83.81                   | .0422                    | .1733                   | 32          |
| 34          | 85.82                   | 71.12     | .01196                   | 0.4937                  | 83.59                      | 2.026                     | 19.88                    | 65.15                     | 84.03                   | .0433                    | .1732                   | 34          |
| 36          | 88.77                   | 74.07     | .01200                   | 0.4774                  | 83.33                      | 2.095                     | 20.44                    | 65.80                     | 84.24                   | .0444                    | .1731                   | 36          |
| 38          | 91.80                   | 77.10     | .01204                   | 0.4617                  | 83.07                      | 2.166                     | 21.01                    | 66.44                     | 84.45                   | .0455                    | .1730                   | 38          |

\*Inches of mercury below one atmosphere.

Courtesy of E. I. du Pont de Nemours &amp; Co. 1963



TABLE 8—PROPERTIES OF REFRIGERANT 502, LIQUID AND SATURATED VAPOR (Contd)

| TEMP<br>(F) | PRESSURE<br>(lb/sq in.) |           | VOLUME<br>(cu ft/lb)     |                         | DENSITY<br>(lb/cu ft)      |                           | ENTHALPY<br>(Btu/lb)     |                           |                         | ENTROPY<br>(Btu/lb-R)    |                         | TEMP<br>(F) |
|-------------|-------------------------|-----------|--------------------------|-------------------------|----------------------------|---------------------------|--------------------------|---------------------------|-------------------------|--------------------------|-------------------------|-------------|
|             | Absolute<br>P           | Gage<br>P | Liquid<br>v <sub>l</sub> | Vapor<br>v <sub>g</sub> | Liquid<br>1/v <sub>l</sub> | Vapor<br>1/v <sub>g</sub> | Liquid<br>h <sub>l</sub> | Latent<br>h <sub>fg</sub> | Vapor<br>h <sub>g</sub> | Liquid<br>s <sub>l</sub> | Vapor<br>s <sub>g</sub> |             |
| 40          | 94.90                   | 80.20     | 0.01208                  | 0.4466                  | 82.80                      | 2.239                     | 21.57                    | 63.09                     | 84.06                   | 0.0466                   | 0.1729                  | 40          |
| 42          | 98.08                   | 83.38     | .01212                   | 0.4321                  | 82.53                      | 2.314                     | 22.14                    | 62.73                     | 84.87                   | .0478                    | .1728                   | 42          |
| 44          | 101.3                   | 86.64     | .01216                   | 0.4182                  | 82.26                      | 2.391                     | 22.71                    | 62.36                     | 85.07                   | .0489                    | .1727                   | 44          |
| 46          | 104.7                   | 89.97     | .01220                   | 0.4047                  | 81.99                      | 2.471                     | 23.28                    | 61.99                     | 85.27                   | .0500                    | .1726                   | 46          |
| 48          | 108.1                   | 93.39     | .01224                   | 0.3918                  | 81.72                      | 2.552                     | 23.85                    | 61.62                     | 85.47                   | .0511                    | .1725                   | 48          |
| 50          | 111.6                   | 96.89     | 0.01228                  | 0.3793                  | 81.44                      | 2.636                     | 24.42                    | 61.25                     | 85.67                   | 0.0522                   | 0.1724                  | 50          |
| 52          | 115.2                   | 100.5     | .01232                   | 0.3673                  | 81.17                      | 2.722                     | 25.00                    | 60.87                     | 85.87                   | .0533                    | .1723                   | 52          |
| 54          | 118.8                   | 104.1     | .01236                   | 0.3557                  | 80.89                      | 2.811                     | 25.58                    | 60.48                     | 86.06                   | .0544                    | .1722                   | 54          |
| 56          | 122.6                   | 107.9     | .01241                   | 0.3446                  | 80.61                      | 2.902                     | 26.16                    | 60.09                     | 86.25                   | .0555                    | .1721                   | 56          |
| 58          | 126.4                   | 111.7     | .01245                   | 0.3338                  | 80.33                      | 2.996                     | 26.73                    | 59.70                     | 86.43                   | .0566                    | .1720                   | 58          |
| 60          | 130.3                   | 115.6     | 0.01249                  | 0.3234                  | 80.04                      | 3.092                     | 27.32                    | 59.30                     | 86.62                   | 0.0578                   | 0.1719                  | 60          |
| 62          | 134.3                   | 119.6     | .01254                   | 0.3134                  | 79.76                      | 3.191                     | 27.91                    | 58.89                     | 86.80                   | .0589                    | .1717                   | 62          |
| 64          | 138.4                   | 123.7     | .01258                   | 0.3037                  | 79.47                      | 3.292                     | 28.48                    | 58.49                     | 86.97                   | .0600                    | .1716                   | 64          |
| 66          | 142.6                   | 127.9     | .01253                   | 0.2944                  | 79.18                      | 3.397                     | 29.08                    | 58.07                     | 87.15                   | .0611                    | .1715                   | 66          |
| 68          | 146.9                   | 132.2     | .01268                   | 0.2854                  | 78.88                      | 3.504                     | 29.67                    | 57.65                     | 87.32                   | .0622                    | .1714                   | 68          |
| 70          | 151.3                   | 136.6     | 0.01272                  | 0.2766                  | 78.59                      | 3.615                     | 30.25                    | 57.23                     | 87.48                   | 0.0633                   | 0.1713                  | 70          |
| 72          | 155.8                   | 141.1     | .01277                   | 0.2682                  | 78.29                      | 3.728                     | 30.85                    | 56.80                     | 87.65                   | .0644                    | .1712                   | 72          |
| 74          | 160.3                   | 145.6     | .01282                   | 0.2601                  | 77.99                      | 3.845                     | 31.45                    | 56.36                     | 87.81                   | .0655                    | .1711                   | 74          |
| 76          | 165.0                   | 150.3     | .01287                   | 0.2522                  | 77.68                      | 3.965                     | 32.04                    | 55.92                     | 87.96                   | .0665                    | .1709                   | 76          |
| 78          | 169.8                   | 155.1     | .01292                   | 0.2446                  | 77.38                      | 4.089                     | 32.64                    | 55.47                     | 88.11                   | .0676                    | .1708                   | 78          |
| 80          | 174.6                   | 159.9     | 0.01298                  | 0.2372                  | 77.07                      | 4.216                     | 33.24                    | 55.02                     | 88.26                   | 0.0687                   | 0.1707                  | 80          |
| 82          | 179.6                   | 164.9     | .01303                   | 0.2300                  | 76.76                      | 4.347                     | 33.84                    | 54.56                     | 88.40                   | .0698                    | .1706                   | 82          |
| 84          | 184.7                   | 170.0     | .01308                   | 0.2231                  | 76.44                      | 4.482                     | 34.45                    | 54.09                     | 88.54                   | .0709                    | .1704                   | 84          |
| 86          | 189.8                   | 175.1     | .01314                   | 0.2164                  | 76.13                      | 4.621                     | 35.06                    | 53.62                     | 88.68                   | .0720                    | .1703                   | 86          |
| 88          | 195.1                   | 180.4     | .01319                   | 0.2099                  | 75.80                      | 4.763                     | 35.67                    | 53.14                     | 88.81                   | .0731                    | .1701                   | 88          |
| 90          | 200.5                   | 185.8     | 0.01325                  | 0.2036                  | 75.48                      | 4.911                     | 36.28                    | 52.65                     | 88.93                   | 0.0742                   | 0.1700                  | 90          |
| 92          | 206.0                   | 191.3     | .01331                   | 0.1976                  | 75.15                      | 5.062                     | 36.89                    | 52.16                     | 89.05                   | .0753                    | .1698                   | 92          |
| 94          | 211.6                   | 196.9     | .01337                   | 0.1916                  | 74.82                      | 5.218                     | 37.51                    | 51.65                     | 89.16                   | .0764                    | .1697                   | 94          |
| 96          | 217.3                   | 202.6     | .01343                   | 0.1859                  | 74.48                      | 5.379                     | 38.13                    | 51.14                     | 89.27                   | .0775                    | .1695                   | 96          |
| 98          | 223.1                   | 208.4     | .01349                   | 0.1804                  | 74.15                      | 5.545                     | 38.75                    | 50.62                     | 89.37                   | .0786                    | .1693                   | 98          |
| 100         | 229.1                   | 214.4     | 0.01355                  | 0.1750                  | 73.80                      | 5.716                     | 39.37                    | 50.10                     | 89.47                   | 0.0796                   | 0.1692                  | 100         |
| 102         | 235.1                   | 220.4     | .01361                   | 0.1697                  | 73.45                      | 5.892                     | 40.00                    | 49.56                     | 89.56                   | .0807                    | .1690                   | 102         |
| 104         | 241.3                   | 226.6     | .01368                   | 0.1646                  | 73.10                      | 6.074                     | 40.62                    | 49.02                     | 89.64                   | .0818                    | .1688                   | 104         |
| 106         | 247.6                   | 232.9     | .01375                   | 0.1597                  | 72.74                      | 6.262                     | 41.25                    | 48.47                     | 89.72                   | .0829                    | .1686                   | 106         |
| 108         | 254.0                   | 239.3     | .01382                   | 0.1549                  | 72.38                      | 6.456                     | 41.88                    | 47.90                     | 89.78                   | .0840                    | .1684                   | 108         |
| 110         | 260.5                   | 245.8     | 0.01389                  | 0.1502                  | 72.01                      | 6.656                     | 42.52                    | 47.33                     | 89.85                   | 0.0851                   | 0.1682                  | 110         |
| 112         | 267.1                   | 252.4     | .01396                   | 0.1457                  | 71.64                      | 6.863                     | 43.15                    | 46.75                     | 89.90                   | .0862                    | .1679                   | 112         |
| 114         | 273.9                   | 259.2     | .01403                   | 0.1413                  | 71.26                      | 7.078                     | 43.79                    | 46.15                     | 89.94                   | .0872                    | .1677                   | 114         |
| 116         | 280.8                   | 266.1     | .01411                   | 0.1370                  | 70.87                      | 7.299                     | 44.43                    | 45.55                     | 89.98                   | .0883                    | .1674                   | 116         |
| 118         | 287.8                   | 273.1     | .01419                   | 0.1328                  | 70.48                      | 7.528                     | 45.07                    | 44.93                     | 90.00                   | .0894                    | .1672                   | 118         |
| 120         | 295.0                   | 280.3     | 0.01427                  | 0.1288                  | 70.08                      | 7.765                     | 45.71                    | 44.31                     | 90.02                   | 0.0905                   | 0.1669                  | 120         |
| 122         | 302.2                   | 287.5     | .01435                   | 0.1248                  | 69.68                      | 8.011                     | 46.36                    | 43.67                     | 90.03                   | .0916                    | .1666                   | 122         |
| 124         | 309.7                   | 295.0     | .01444                   | 0.1210                  | 69.26                      | 8.265                     | 47.00                    | 43.02                     | 90.02                   | .0926                    | .1663                   | 124         |
| 126         | 317.2                   | 302.5     | .01453                   | 0.1173                  | 68.84                      | 8.529                     | 47.65                    | 42.36                     | 90.01                   | .0937                    | .1660                   | 126         |
| 128         | 324.9                   | 310.2     | .01462                   | 0.1136                  | 68.41                      | 8.802                     | 48.29                    | 41.69                     | 89.98                   | .0948                    | .1657                   | 128         |
| 130         | 332.7                   | 318.0     | 0.01471                  | 0.1101                  | 67.96                      | 9.086                     | 48.95                    | 41.00                     | 89.95                   | 0.0958                   | 0.1654                  | 130         |
| 132         | 340.6                   | 325.9     | .01481                   | 0.1066                  | 67.51                      | 9.380                     | 49.59                    | 40.30                     | 89.98                   | .0969                    | .1650                   | 132         |
| 134         | 348.7                   | 334.0     | .01491                   | 0.1032                  | 67.05                      | 9.685                     | 50.24                    | 39.59                     | 89.83                   | .0979                    | .1646                   | 134         |
| 136         | 357.0                   | 342.3     | .01502                   | 0.09997                 | 66.58                      | 10.00                     | 50.88                    | 38.87                     | 89.75                   | .0990                    | .1642                   | 136         |
| 138         | 365.3                   | 350.6     | .01513                   | 0.09679                 | 66.09                      | 10.33                     | 51.53                    | 38.13                     | 89.66                   | .1000                    | .1638                   | 138         |
| 140         | 373.8                   | 359.1     | 0.01525                  | 0.09368                 | 65.59                      | 10.67                     | 52.17                    | 37.38                     | 89.55                   | 0.1011                   | 0.1634                  | 140         |
| 142         | 382.5                   | 367.8     | .01537                   | 0.09067                 | 65.07                      | 11.03                     | 52.81                    | 36.62                     | 89.43                   | .1021                    | .1630                   | 142         |
| 144         | 391.3                   | 376.6     | .01549                   | 0.08773                 | 64.54                      | 11.40                     | 53.45                    | 35.84                     | 89.29                   | .1031                    | .1625                   | 144         |
| 146         | 400.3                   | 385.6     | .01563                   | 0.08489                 | 63.99                      | 11.78                     | 54.08                    | 35.06                     | 89.14                   | .1041                    | .1620                   | 146         |
| 148         | 409.4                   | 394.7     | .01577                   | 0.08213                 | 63.42                      | 12.18                     | 54.70                    | 34.27                     | 88.97                   | .1051                    | .1615                   | 148         |
| 150         | 418.6                   | 403.9     | 0.01591                  | 0.07946                 | 62.84                      | 12.59                     | 55.32                    | 33.47                     | 88.79                   | 0.1061                   | 0.1610                  | 150         |
| 152         | 428.1                   | 413.4     | .01607                   | 0.07688                 | 62.22                      | 13.01                     | 55.92                    | 32.68                     | 88.60                   | .1070                    | .1604                   | 152         |
| 154         | 437.6                   | 422.9     | .01624                   | 0.07441                 | 61.59                      | 13.44                     | 56.51                    | 31.88                     | 88.39                   | .1079                    | .1599                   | 154         |
| 156         | 447.4                   | 432.7     | .01641                   | 0.07204                 | 60.92                      | 13.88                     | 57.10                    | 31.08                     | 88.18                   | .1088                    | .1593                   | 156         |
| 158         | 457.2                   | 442.5     | .01661                   | 0.06978                 | 60.22                      | 14.33                     | 57.66                    | 30.30                     | 87.96                   | .1097                    | .1587                   | 158         |
| 160         | 467.3                   | 452.6     | 0.01681                  | 0.06764                 | 59.49                      | 14.78                     | 58.21                    | 29.53                     | 87.74                   | 0.1105                   | 0.1582                  | 160         |

## CHAPTER 2. BRINES

This chapter provides information to guide the engineer in the selection of brines, and includes the properties of the commonly used brines.

At temperatures above 32 F, water is the most commonly used heat transfer medium for conveying a refrigeration load to an evaporator. At temperatures below 32 F, brines are used. They may be:

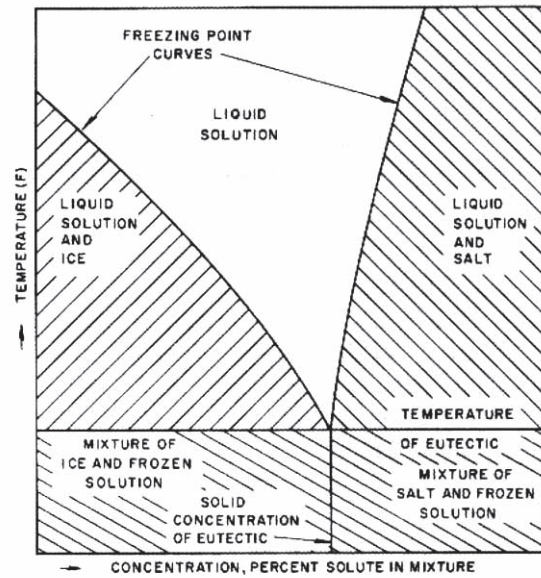
1. An aqueous solution of inorganic salts, i.e. sodium chloride or calcium chloride. For low temperatures, a eutectic mixture may be used.
2. An aqueous solution of organic compounds, i.e. alcohols or glycols. Ethanol water, methanol water, ethylene glycol and propylene glycol are examples.
3. Chlorinated or fluorinated hydrocarbons and halocarbons.

A solution of any salt in water, or in general any solution, has a certain concentration at which the freezing point is at a minimum. A solution of such a concentration is called a eutectic mixture. The temperature at which it freezes is the eutectic temperature. A solution at any other concentration starts to freeze at a higher temperature. *Figure 11* illustrates the relationship between the freezing point (temperature) of a brine mixture and the percent of solute in the mixture (concentration). *Chart 18* covers a range of temperatures wide enough to reveal the two freezing point curves.

When the temperature of a brine with a concentration below the eutectic falls below the freezing point, ice crystals form and the concentration of the residual solution increases until at the eutectic temperature the remaining solution reaches a eutectic concentration. Below this temperature the mixture solidifies to form a mechanical mixture of ice and frozen eutectic solution.

When the temperature of a brine with a concentration above the eutectic falls below the freezing point, salt crystallizes out and the concentration of the residual solution decreases until at the eutectic temperature the remaining solution reaches a eutectic concentration. Below this temperature the mixture solidifies to form a mechanical mixture of salt and frozen eutectic solution.

This chapter includes a discussion of these brines, also tables and charts indicating properties.



Courtesy of ASHRAE Guide and Data Book 1963

FIG. 11-BRINE MIXTURE

### BRINE SELECTION

The selection of a brine is based upon a consideration of the following factors:

1. *Freezing Point* -Brine must be suitable for the lowest operating temperature.
2. *Application* -When using an open piping system, the possibility of product contamination by the brine should be checked.
3. *Cost* -The initial charge and quantity of make-up required are factors in the determination of costs.
4. *Safety* -Toxicity and flammability of brine.
5. *Thermal Performance* -Viscosity, specific gravity, specific heat and thermal conductivity are utilized to determine thermal performance.
6. *Suitability* -Piping and system equipment material require a stable and relatively corrosive-free brine.
7. *Codes* -Brine must be acceptable by codes, ordinances, regulatory agencies and insuror.



TABLE 9-TYPICAL BRINE APPLICATIONS

|   | Sodium Chloride | Calcium Chloride | Ethylene Glycol | Propylene Glycol | Methanol Water | Ethanol Water | Chlorinated or Fluorinated Hydrocarbons |
|---|-----------------|------------------|-----------------|------------------|----------------|---------------|---|
| Breweries                                   |                 |                  |                 | X                |                |               |   |
| Chemical Plants                             | X               | X                | X               |                  | X              | X             | X                                       |
| Dairies                                     | X               | X                |                 | X                |                |               |   |
| Food Freezing                               | X               | X                |                 | X                |                | X             |   |
| Heat Pumps                                  |                 | X                | X               |                  |                |               | X                                       |
| Meat Packing                                | X               | X                |                 |                  |                |               |   |
| Preheat Coils<br>(Air Conditioning Systems) |                 |                  | X               |                  |                |               |   |
| Skating Rinks                               |                 | X                | X               |                  | X              |               |   |
| Snow Melting                                | X               | X                | X               |                  |                |               |   |
| Low Temperature (Specine)                   |                 | X                | X               |                  |                |               | X                                       |
| Ice Cream                                   |                 | X                |                 | X                |                |               |   |

The most common brines are aqueous solutions of calcium chloride or sodium chloride. Although both of these brines have the advantage of low cost, they have the disadvantage of being corrosive. To overcome corrosion, an inhibitor may be added to the brine. Sodium dichromate is a satisfactory and economical inhibitor. Sodium hydroxide is added to keep the brine slightly alkaline.

Sodium chloride is cheaper than calcium chloride brine; however, it cannot be used below its eutectic point of -6 F. It is preferred where contact with calcium chloride brine cannot be tolerated, for example, with unsealed foodstuffs. The use of calcium chloride of commercial grade is not satisfactory below -40 F.

Systems using aqueous solutions of alcohol or glycol are more susceptible to leakage than those using salts. A disadvantage of alcohol is its flammability. It is utilized mainly in industrial processes where similar hazards already exist, and in the same temperature range as the salts (down to -40 F). The toxicity of methanol water (wood alcohol) is a disadvantage. Conversely, the non-toxicity of ethanol water (denatured grain alcohol) is an advantage.

Corrosion inhibitors should be used with alcohol type brines as recommended by the manufacturer of the alcohol.

Aqueous solutions of glycol are utilized mainly in commercial applications as opposed to industrial processes. Ethylene and propylene glycol possess equal corrosiveness which an inhibitor can neutralize. Galvanized surfaces are particularly prone to attack by the glycols and should be avoided.

An inhibitor and potable water are recommended for making up glycol brines. The glycol manufacturer should be consulted for inhibitor recommendations. Some manufacturers have a brine sample analysis service to assist in maintaining a satisfactory brine condition in the system. Heat transfer glycols are available with nonoily inhibitors which do not penalize heat transfer qualities (sodium nitrite or borox).

Glycols can be used as heat transfer media at relatively high temperatures. With stabilizers, glycol oxidation in air at high temperatures is eliminated for all practical purposes.

Ethylene glycol is more toxic than propylene glycol, but less toxic than methanol water. Propylene glycol is preferred to ethylene glycol in food freezing for example.

Chlorinated and fluorinated hydrocarbons are expensive and are used in very low temperature work (below -40 F).

Table 8 presents typical application for the various brines.

Load, brine quantity and temperature rise are all related to each other so that, when any two are known, the third may be found by the formula:

$$\text{Load (tons)} = \frac{\text{gpm} \times \text{temp rise (F)} \times \text{sp gr} \times C_p}{24}$$

where:

sp gr = specific gravity of brine

$C_p$  = specific heat of brine (Btu/lb-F)

## PIPING

All materials in the piping system including flange gaskets, valve seats and packing, pump seals and other specialties must be compatible with the brine. Copper tubing (except for the salt brines) and standard steel pipe are suitable for general use.

The pump rating and motor horsepower should be based on the particular brine used and the actual operating temperature.

## FRICTION LOSS

To determine the friction loss in a brine piping system, the engineer should first calculate the loss as if water were being used. A multiplier is then used to convert the calculated loss to the actual loss for the brine system. The multiplier is calculated as follows:

$$\text{Multiplier} = \text{sp gr} \times \frac{f_b}{f_w}$$

where:

sp gr = specific gravity of brine

$f_b$  = friction factor for the brine

$f_w$  = friction factor for water at the brine velocity

Friction factor is determined from the Reynolds number. The Reynolds number is:

$$\text{Re} = \frac{7740 \times d \times v \times \text{sp gr}}{\mu'}$$

where:

d = inside pipe diameter (in.)

v = brine velocity (ft/sec)

sp gr = specific gravity of brine =  $\frac{1\text{b/cu ft}}{62.5}$

$$\mu' = \text{viscosity (centipoises)} = \frac{\text{absolute viscosity, 1b/(hr) (ft)}}{2.42}$$

*Example 1* illustrates the use of the multiplier to determine the brine friction loss thru a heat transfer coil.

### Example 1- Friction Loss Multiplier

Given:

A 5/8 in. copper tube coil with a circuit water velocity of 4.29 ft/sec and a pressure drop of 7.5 psi.

Mean water temperature = 55 F.

Find:

Friction loss multiplier and pressure drop when using ethylene glycol at a mean brine temperature of 92.5 F and 41% solution by weight at the same circuit liquid velocity.

Solution:

Refer to *Chart 1*.

$$\frac{\epsilon}{d} = \frac{.00006}{.575} = .000104$$

where:

$\epsilon$  = absolute roughness of drawn tubing

d = inside diameter of 5/8 in. copper tubing

Refer to *Chart 19*.

Specific gravity of ethylene glycol at a mean brine temperature of 92.5 F and 41% solution by weight is 1.05.

Refer to *Chart 18*.

Viscosity of ethylene glycol at the same condition equals 2.1 centipoises.

$$\text{Re} = \frac{7740 \times .575 \times 4.29 \times 1.05}{2.1} = 9520 = 9.52 \times 10^3$$

Refer to *Chart 1*.

For a Reynolds number of  $9.52 \times 10^3$  and a relative roughness of .000104, the chart indicates friction factor  $f_b = .031$ .

Specific gravity of fresh water at a mean temperature of 55 F = 1.00

Refer to *Chart 28*.

Viscosity of fresh water at a mean temperature of 55 F = 1.2 centipoises.

$$\text{Re (water)} = \frac{7740 \times .575 \times 4.29 \times 1.00}{1.2} = 15,900 = 1.59 \times 10^4$$

Refer again to *Chart 1*.

For a Reynolds number of  $1.59 \times 10^4$  and a relative roughness of .000104, the chart indicates a friction factor  $f_w = .027$ .

$$\begin{aligned} \text{Friction multiplier} &= \text{sp gr (brine)} \times \frac{f_b}{f_w} \\ &= 1.05 \times \frac{.031}{.027} = 1.21 \end{aligned}$$

Brine friction loss =  $1.21 \times 7.5$  psi = 9.08 psi or

$$= \frac{9.08 \times 2.31}{1.05} = 20.0 \text{ ft brine}$$

## PUMP BRAKE HORSEPOWER

To determine the horsepower required by a pump with brine, the following formula may be used:

$$\text{bhp} = \frac{\text{gpm} \times \text{total head (ft brine)} \times \text{sp gr}}{3960 \times \text{eff}}$$

where:

gpm = gallons/min. of brine

total head = total pump head (ft brine)

sp gr = specific gravity of brine

eff = pump efficiency

## BRINE PROPERTIES

Specific gravity, viscosity, conductivity, specific heat, concentration, and freezing and boiling points are important factors in the consideration of liquids other than water suitable for cooling and heating purposes. High values of specific gravity, conductivity and specific heat, and low values of viscosity, promote a high rate of heat transfer. High values of specific gravity and viscosity result in high pumping head and consequently high

pumping costs. High specific heats are desirable in that they reduce the quantity of liquid required to be circulated or stored for a given duty. Low viscosities are desirable from a standpoint of both rate of heat transfer and low pumping costs. They are particularly desirable at the lower temperatures where the viscosity increases.

Table 9 is a tabulation of the various brines covered in this chapter, giving the properties of these brines at different temperatures and suitable concentrations. Charts 2 to 28 present the viscosity, specific gravity, specific heat and thermal conductivity of the brines for various mean brine temperatures and compositions.

TABLE 10-BRINE PROPERTIES

| Temp.<br>(F) | Brine            | Solution<br>(by wt)<br>(%) | Density<br>(lb/cu ft) | Specific<br>Heat<br>(Btu/lb-F) | Thermal<br>Cond.<br>(Btu/hr<br>-sq ft-F/ft) | Viscosity<br>(Centi-<br>poises) | Freezing<br>Point<br>(F) | Boiling<br>Point<br>(F) | Gpm/ton<br>/10 deg<br>rise | $h_b$<br>* | $V_b$<br>† | Relative<br>Cost per<br>Gal. of<br>Solution |
|--------------|------------------|----------------------------|-----------------------|--------------------------------|---|---------------------------------|--------------------------|-------------------------|----------------------------|------------|------------|---|
| 30           | Sodium Chloride  | 12                         | 68.2                  | .86                            | .28   | 2.2                             | 17.5                     | 215.                    | 2.55                       | 941        | 1.61       | 1   |
|              | Calcium Chloride | 12                         | 69.2                  | .83                            | .32   | 2.4                             | 19.0                     | 213.                    | 2.62                       | 971        | 1.78       | 3   |
|              | Methanol Water   | 15                         | 61.5                  | 1.00                           | .28   | 3.2                             | 13.5                     | 187.                    | 2.45                       | 781        | 2.63       | 13  |
|              | Ethanol Water    | 20                         | 61.0                  | 1.04                           | .27   | 5.5                             | 12.0                     | 189.                    | 2.37                       | 621        | 4.60       | 20  |
|              | Ethylene Glycol  | 25                         | 64.7                  | .92                            | .30   | 3.7                             | 12.9                     | 217.                    | 2.52                       | 775        | 2.92       | 42  |
|              | Propylene Glycol | 30                         | 64.5                  | .94                            | .26   | 8.0                             | 13.0                     | 216.                    | 2.47                       | 525        | 6.35       | 43  |
| 15           | Sodium Chloride  | 21                         | 72.8                  | .80                            | .25   | 4.2                             | 1.0                      | 216.                    | 2.57                       | 693        | 2.90       | 1   |
|              | Calcium Chloride | 20                         | 74.8                  | .72                            | .31   | 4.8                             | 1.0                      | 214.                    | 2.77                       | 730        | 3.28       | 5   |
|              | Methanol Water   | 22                         | 60.4                  | .97                            | .26   | 5.3                             | 4.5                      | 182.                    | 2.56                       | 599        | 4.44       | 19  |
|              | Ethanol Water    | 25                         | 61.0                  | 1.02                           | .25   | 8.2                             | 4.5                      | 187.                    | 2.41                       | 504        | 6.85       | 25  |
|              | Ethylene Glycol  | 35                         | 66.0                  | .86                            | .28   | 6.8                             | 0.0                      | 219.                    | 2.65                       | 576        | 5.25       | 60  |
|              | Propylene Glycol | 40                         | 65.3                  | .89                            | .24   | 20.0                            | -4.2                     | 218.                    | 2.58                       | 103        | ‡          | 58  |
| -5           | Calcium Chloride | 25                         | 78.4                  | .67                            | .29   | 10.3                            | -21.0                    | 215.                    | 2.85                       | 513        | 6.75       | 6   |
|              | Methanol Water   | 35                         | 60.0                  | .89                            | .23   | 9.9                             | -22.0                    | 176.                    | 2.82                       | 98         | 8.40       | 30  |
|              | Ethanol Water    | 36                         | 60.6                  | .95                            | .22   | 13.5                            | -16.0                    | 183.                    | 2.62                       | 97         | ‡          | 35  |
|              | Ethylene Glycol  | 45                         | 67.4                  | .79                            | .25   | 17.2                            | -15.5                    | 223.                    | 2.82                       | 103        | ‡          | 78  |
|              | Propylene Glycol | 50                         | 66.5                  | .83                            | .23   | 80.0                            | -29.0                    | 222.                    | 2.72                       | 98         | ‡          | 75  |
| -30          | Calcium Chloride | 30                         | 82.1                  | .63                            | .28   | 27.8                            | -47.0                    | 216.                    | 2.90                       | 110        | ‡          | 8   |
|              | Methanol Water   | 45                         | 60.0                  | .80                            | .22   | 18.0                            | -45.0                    | 171.                    | 3.13                       | 91         | ‡          | 39  |
|              | Ethanol Water    | 52                         | 59.5                  | .81                            | .19   | 20.2                            | -50.0                    | 179.                    | 3.11                       | 83         | ‡          | 50  |
|              | Ethylene Glycol  | 55                         | 69.0                  | .73                            | .22   | 75.0                            | -43.0                    | 227.                    | 2.98                       | 93         | ‡          | 97  |
|              | Propylene Glycol | 60                         | 67.2                  | .77                            | .21   | 700.0                           | -55.0                    | 227.                    | 2.90                       | 91         | ‡          | 90  |

\* $h_b$  = coefficient of heat transfer between brine and surface (Btu/hr-sq ft.F), at 7 fps velocity for .554 in. ID tubing.

† $V_b$  = minimum brine velocity (ft/sec), at Re=3500 for .554 in. ID tubing.

‡Above 10 ft/sec.

Note that specific gravity for propylene glycol (Chart 23) in the composition range of 50% to 100% (same mean brine temperature, F) is the same for two

compositions. Specific gravity alone, therefore, is not a reliable method of determining the solution composition of this brine.

CHART 1—FRICTION FACTORS FOR COMMERCIAL PIPE

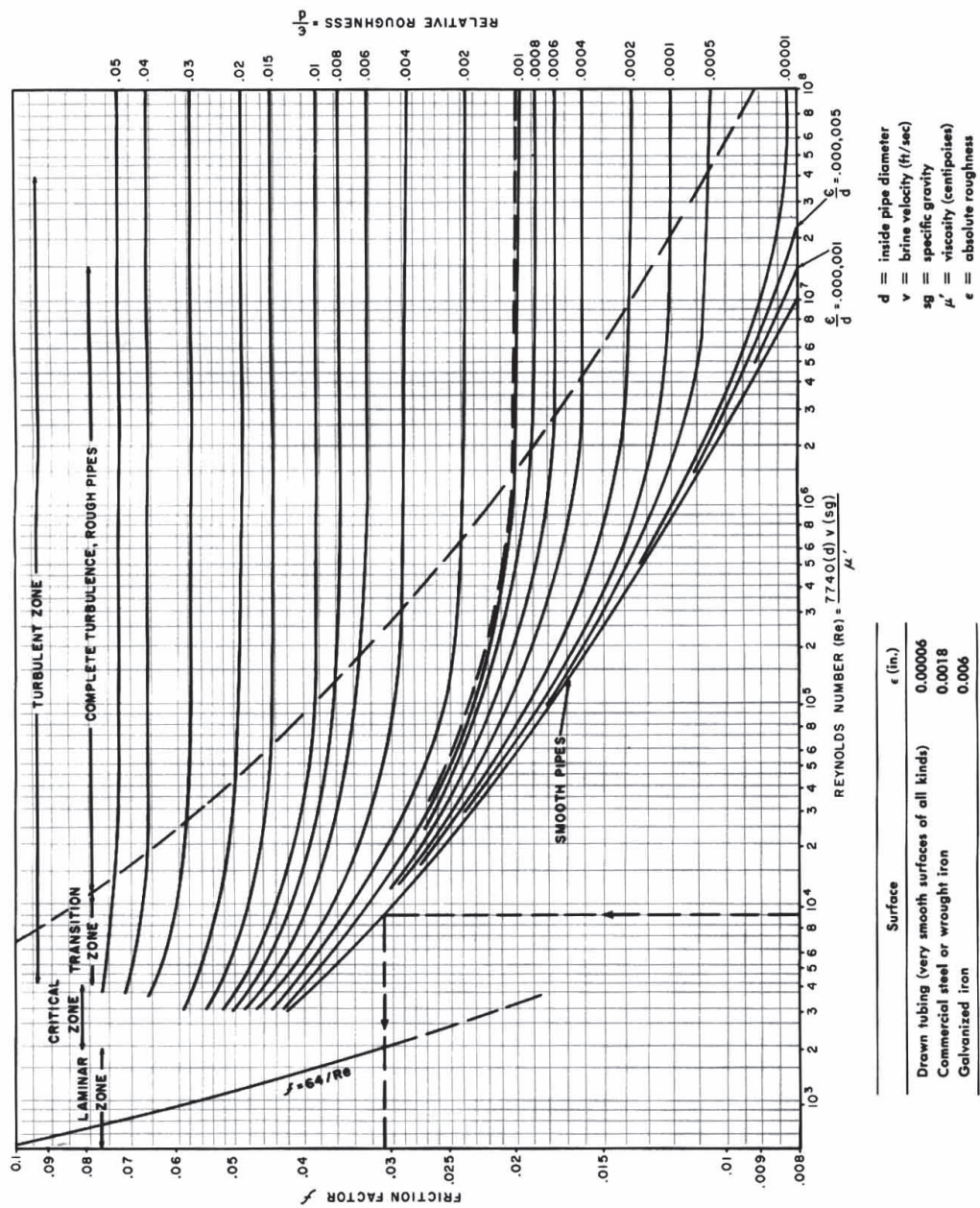




CHART 2-SODIUM CHLORIDE-VISCOSITY

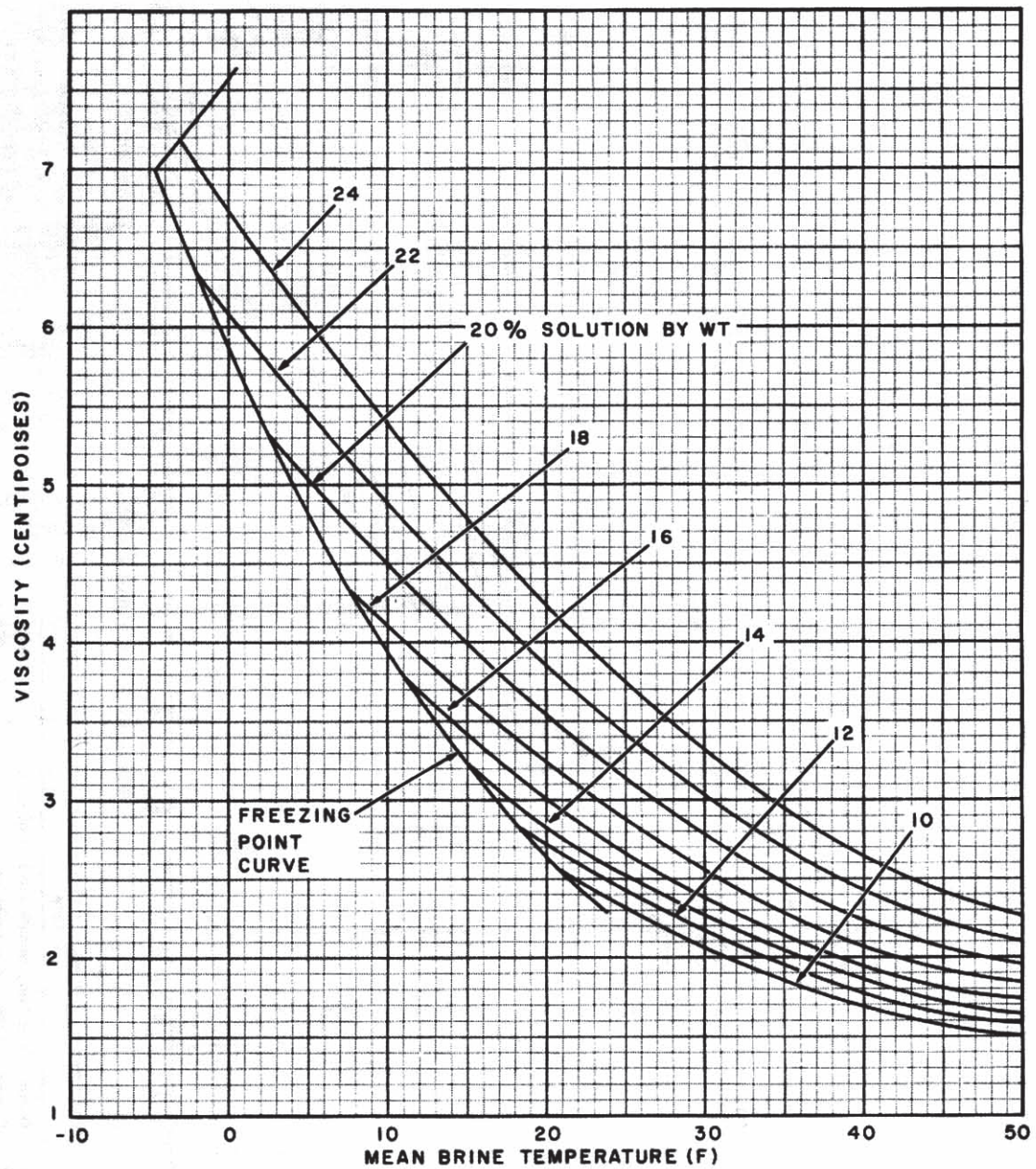
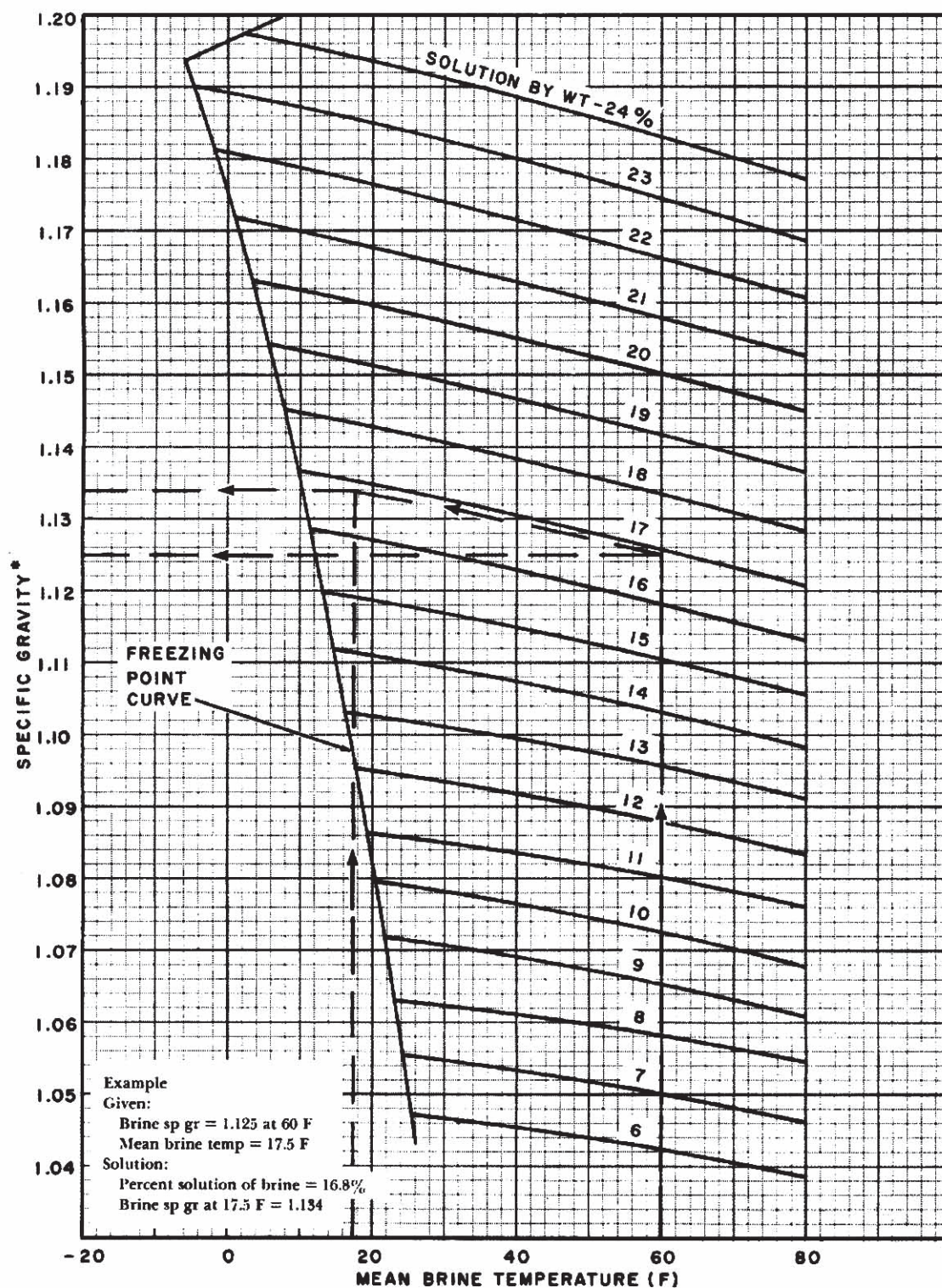




CHART 3-SODIUM CHLORIDE-SPECIFIC GRAVITY

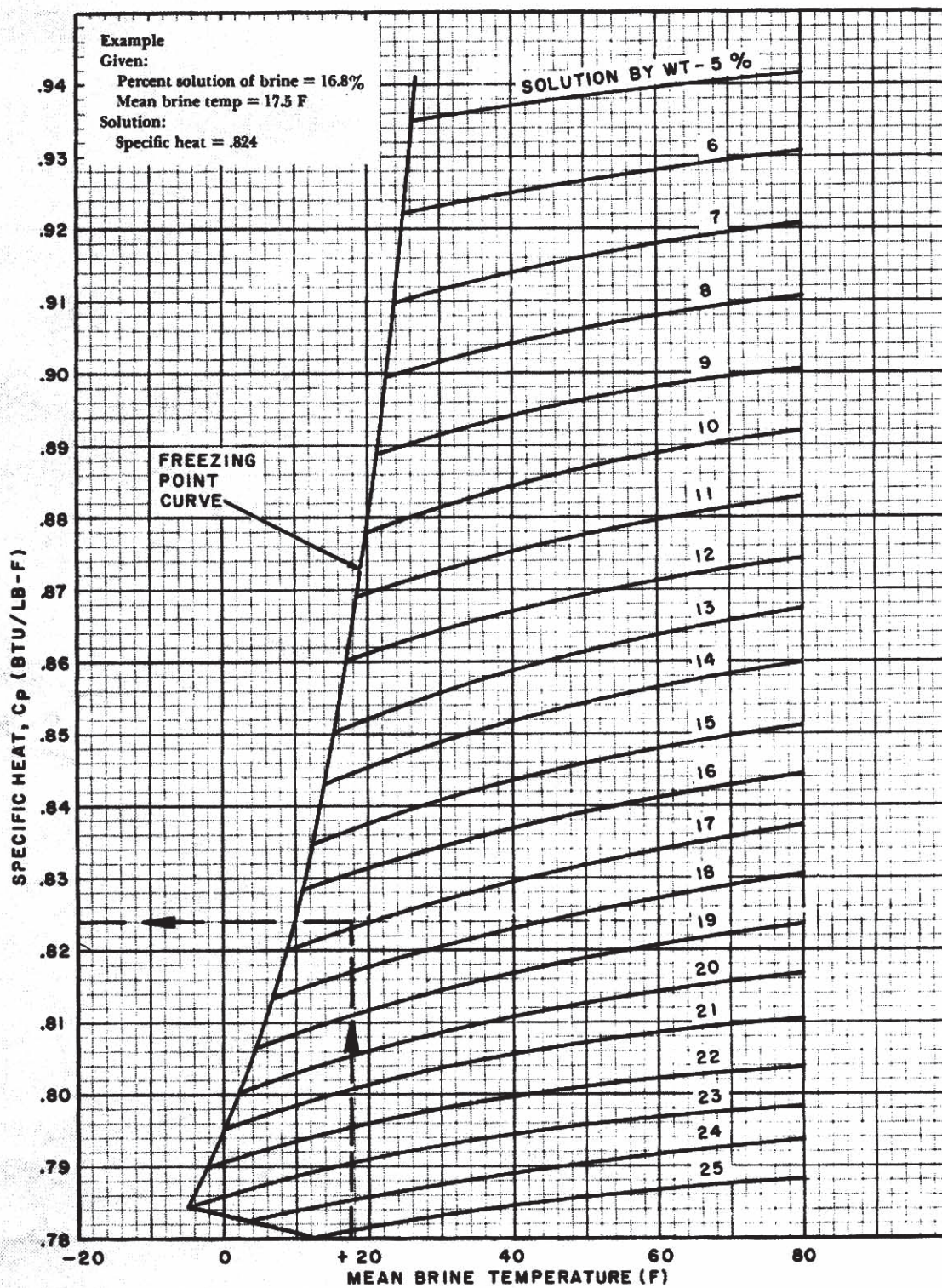


\*With reference to 60 F water.

Courtesy of Dow Chemical Co.



CHART 4-SODIUM CHLORIDE-SPECIFIC HEAT



Courtesy of Dow Chemical Co.



CHART 5-SODIUM CHLORIDE-THERMAL CONDUCTIVITY

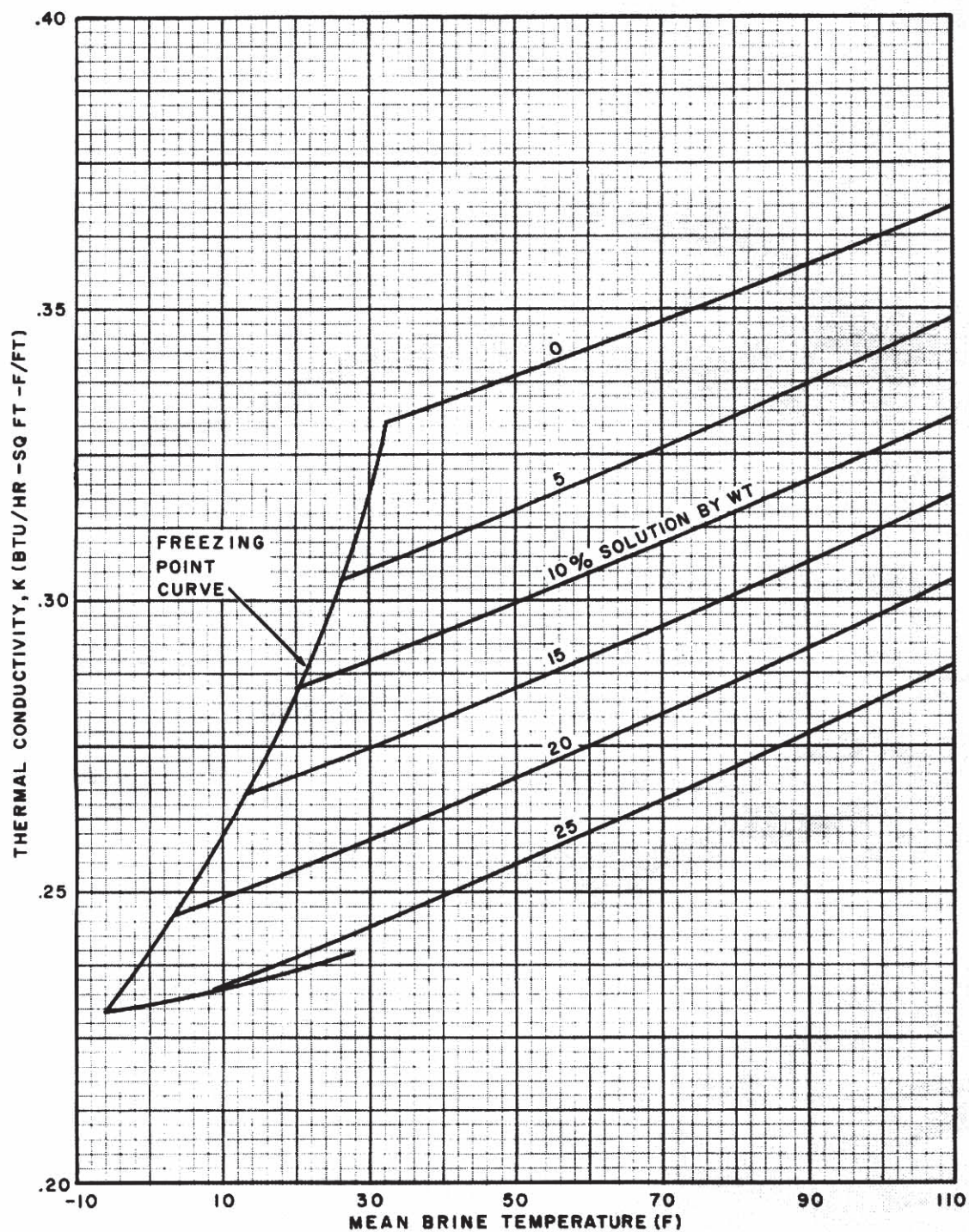




CHART 6-CALCIUM CHLORIDE-VISCOSITY

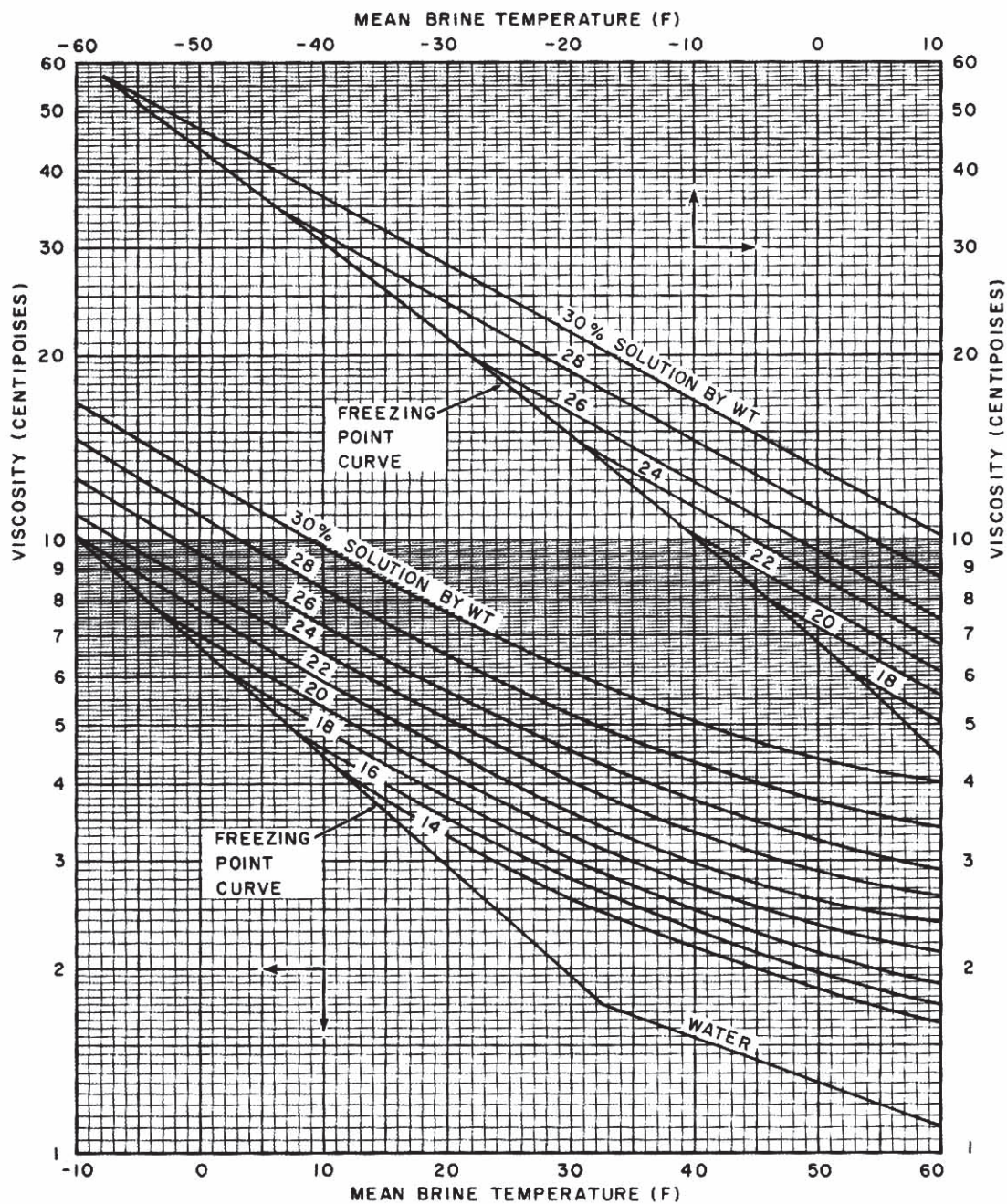
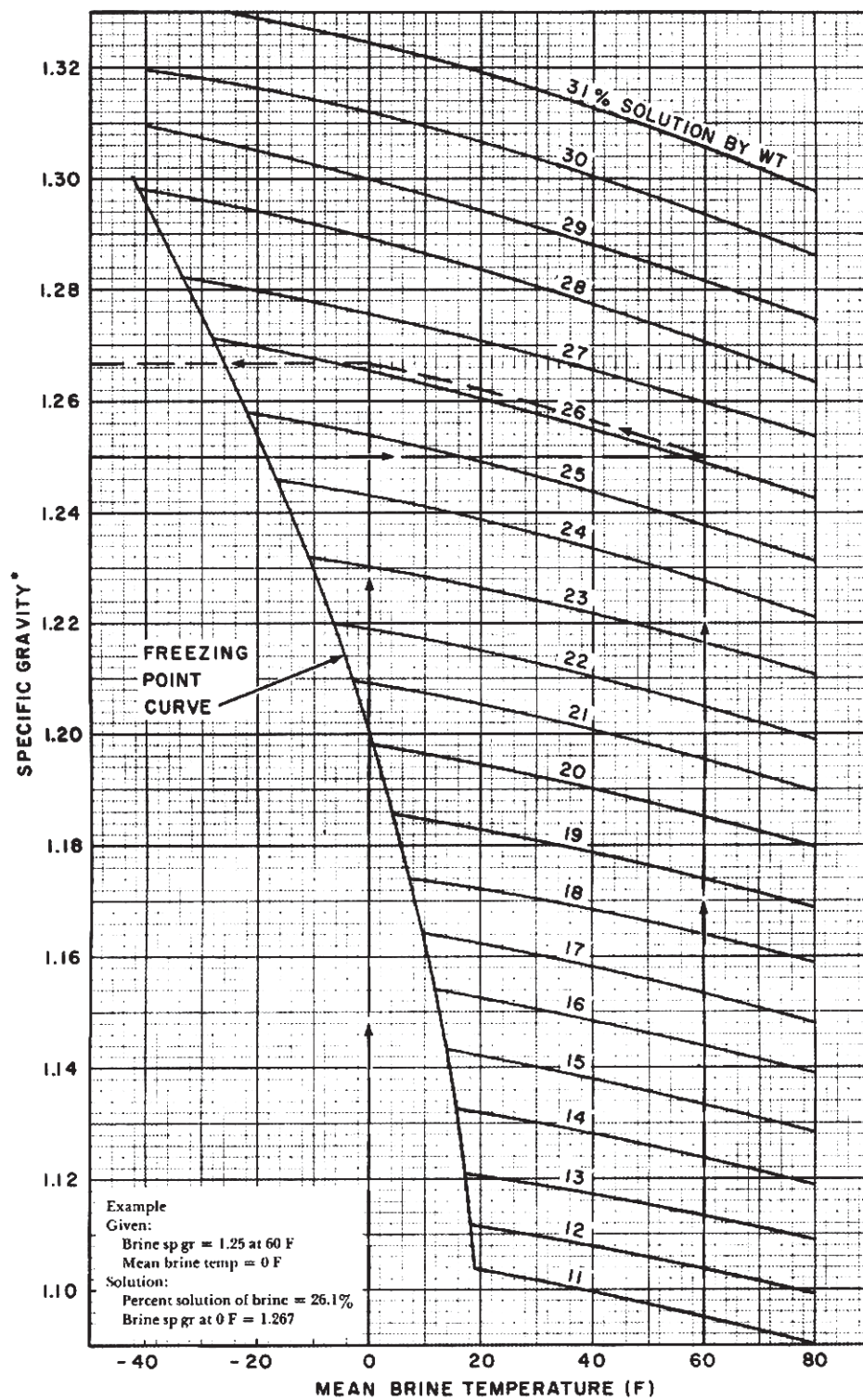




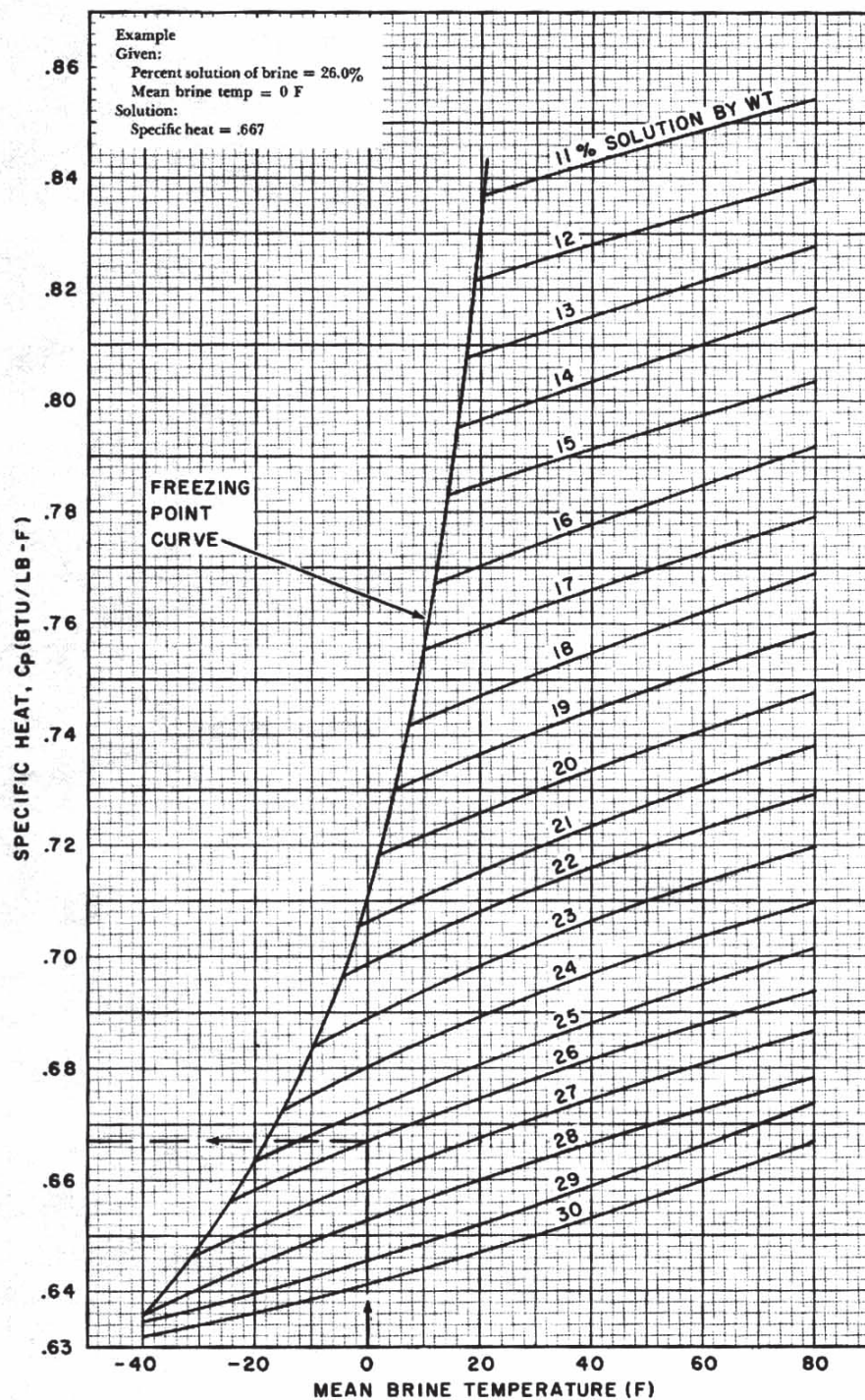
CHART 7-CALCIUM CHLORIDE-SPECIFIC GRAVITY



\*With reference to 60 F water.

Courtesy of Dow Chemical Co.

CHART 8-CALCIUM CHLORIDE-SPECIFIC HEAT



Courtesy of Dow Chemical Co.



CHART 9-CALCIUM CHLORIDE-THERMAL CONDUCTIVITY

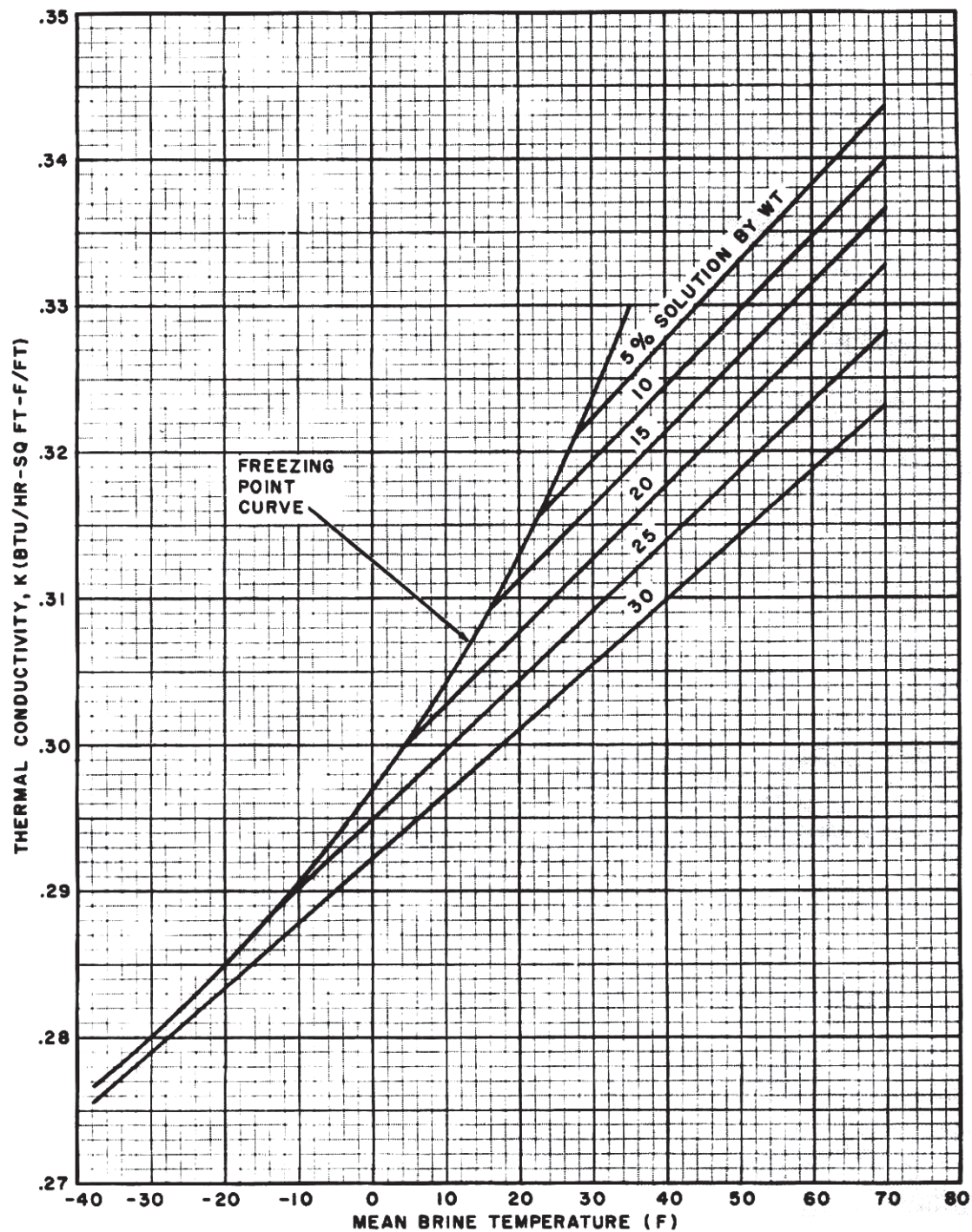
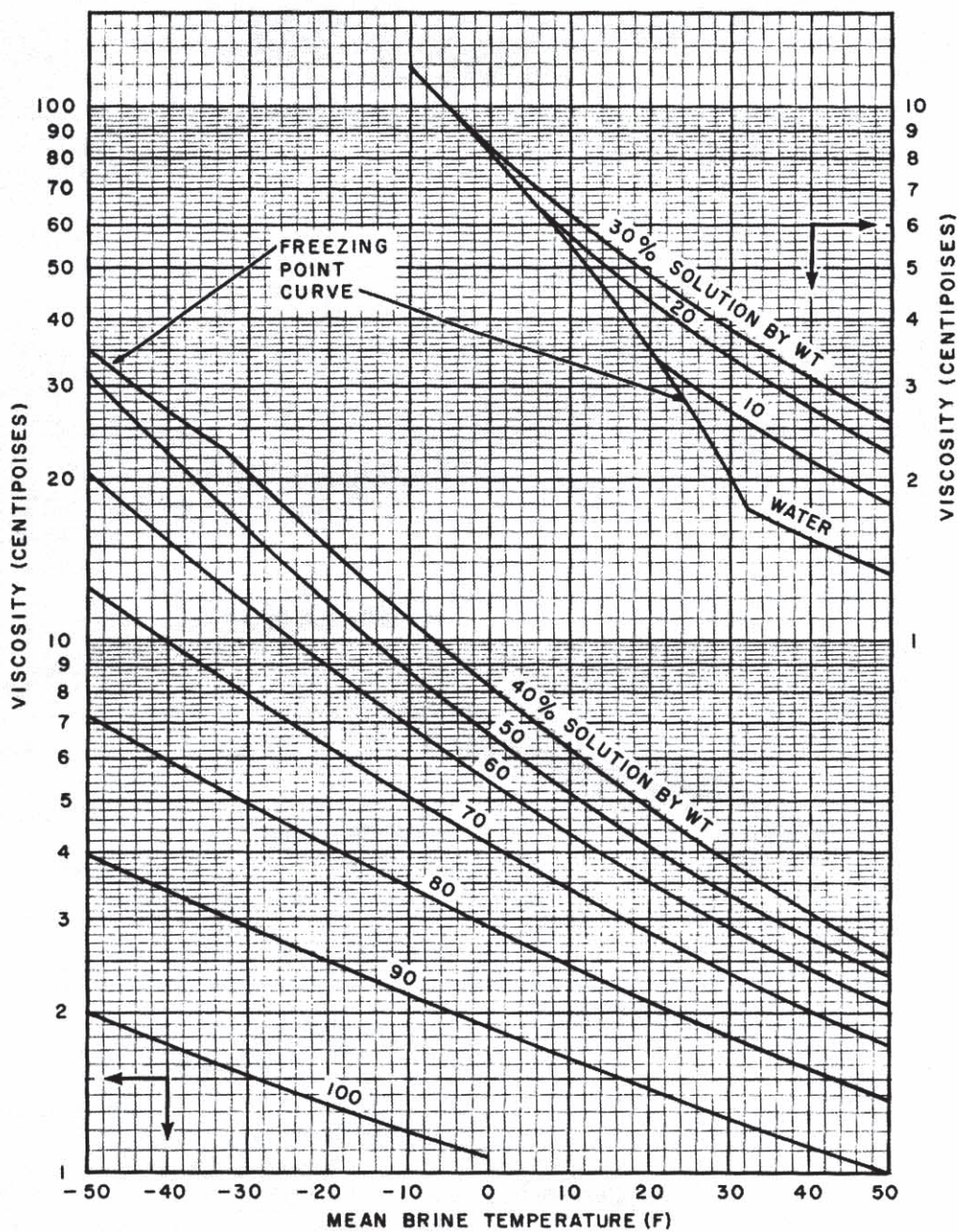




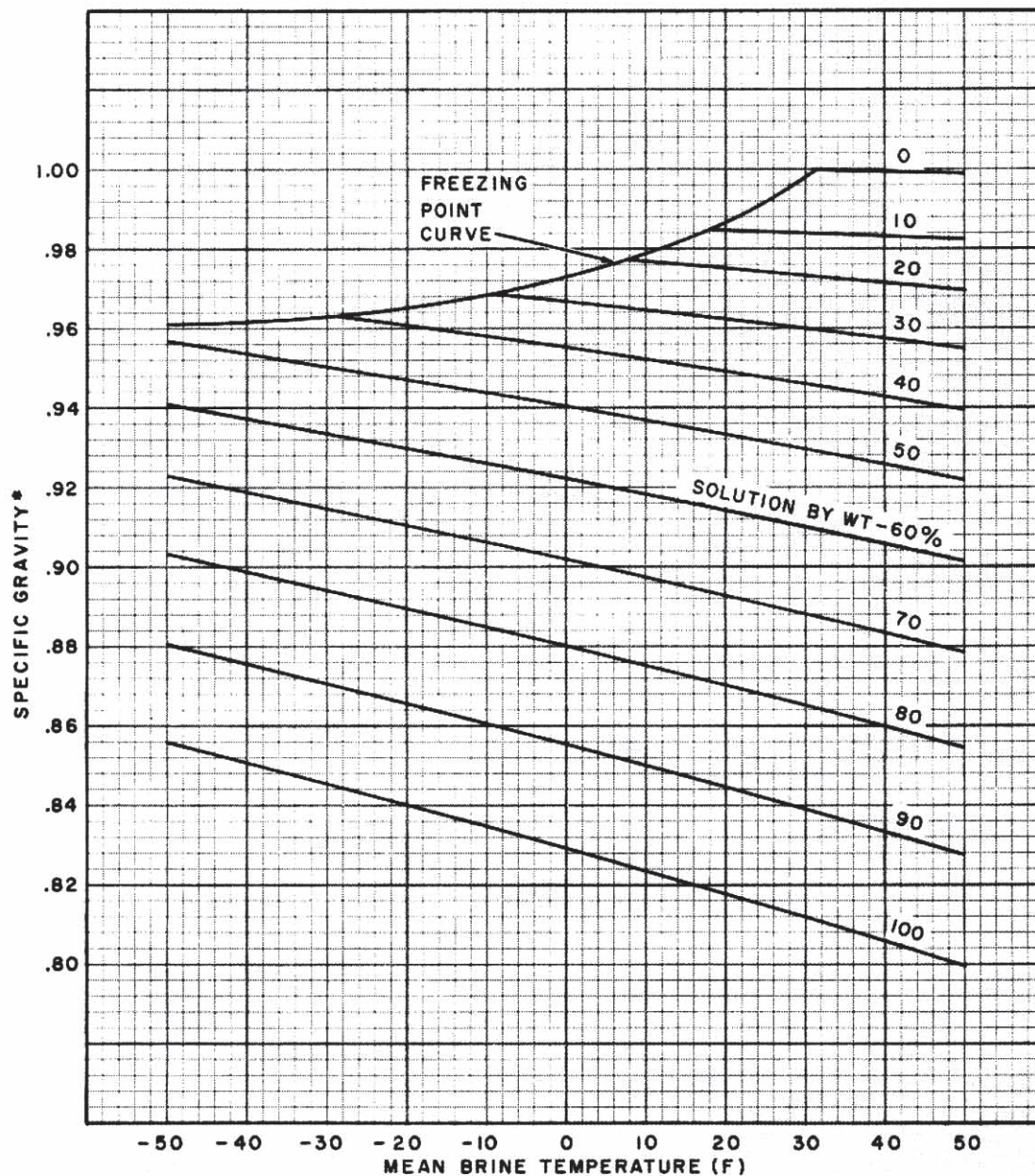
CHART 10-METHANOL BRINE-VISCOSITY



Courtesy of Carbide and Carbon Chemicals Corporation



CHART 11-METHANOL BRINE-SPECIFIC GRAVITY



\*With reference to 60 F water.

Courtesy of Carbide and Carbon Chemicals Corporation



CHART 12-METHANOL BRINE-SPECIFIC HEAT

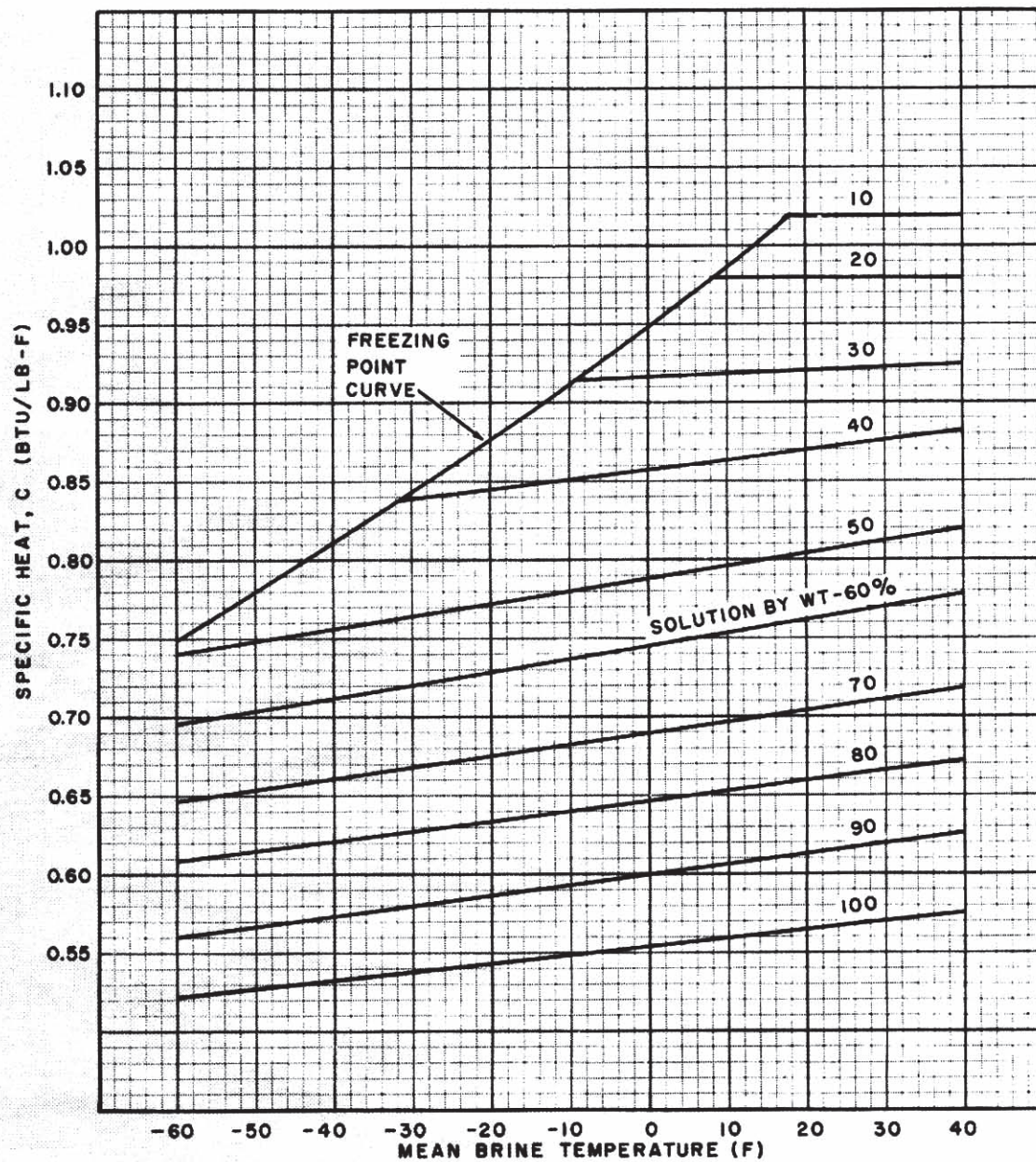




CHART 13-METHANOL BRINE-THERMAL CONDUCTIVITY

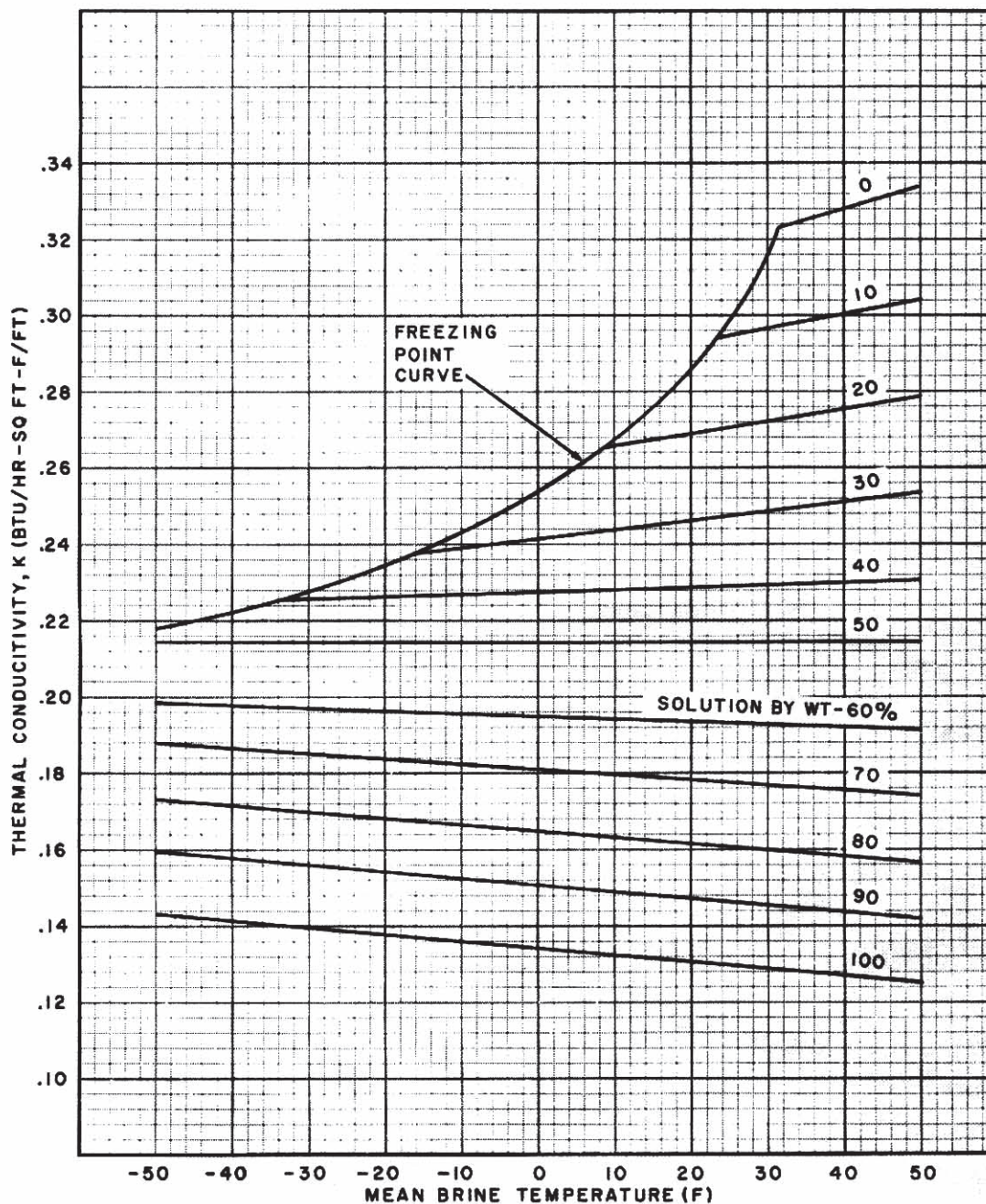




CHART 14-ETHANOL BRINE-VISCOSITY

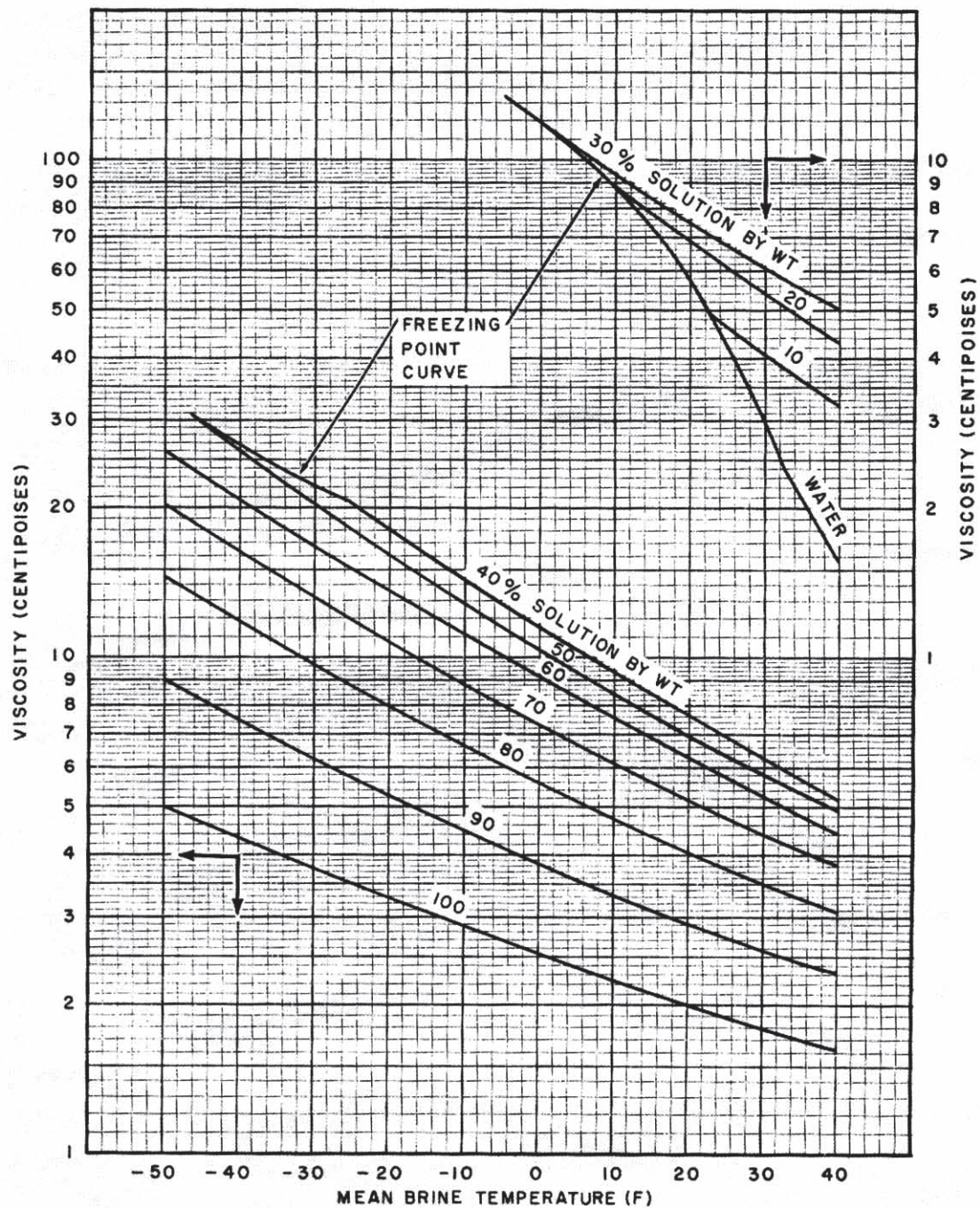
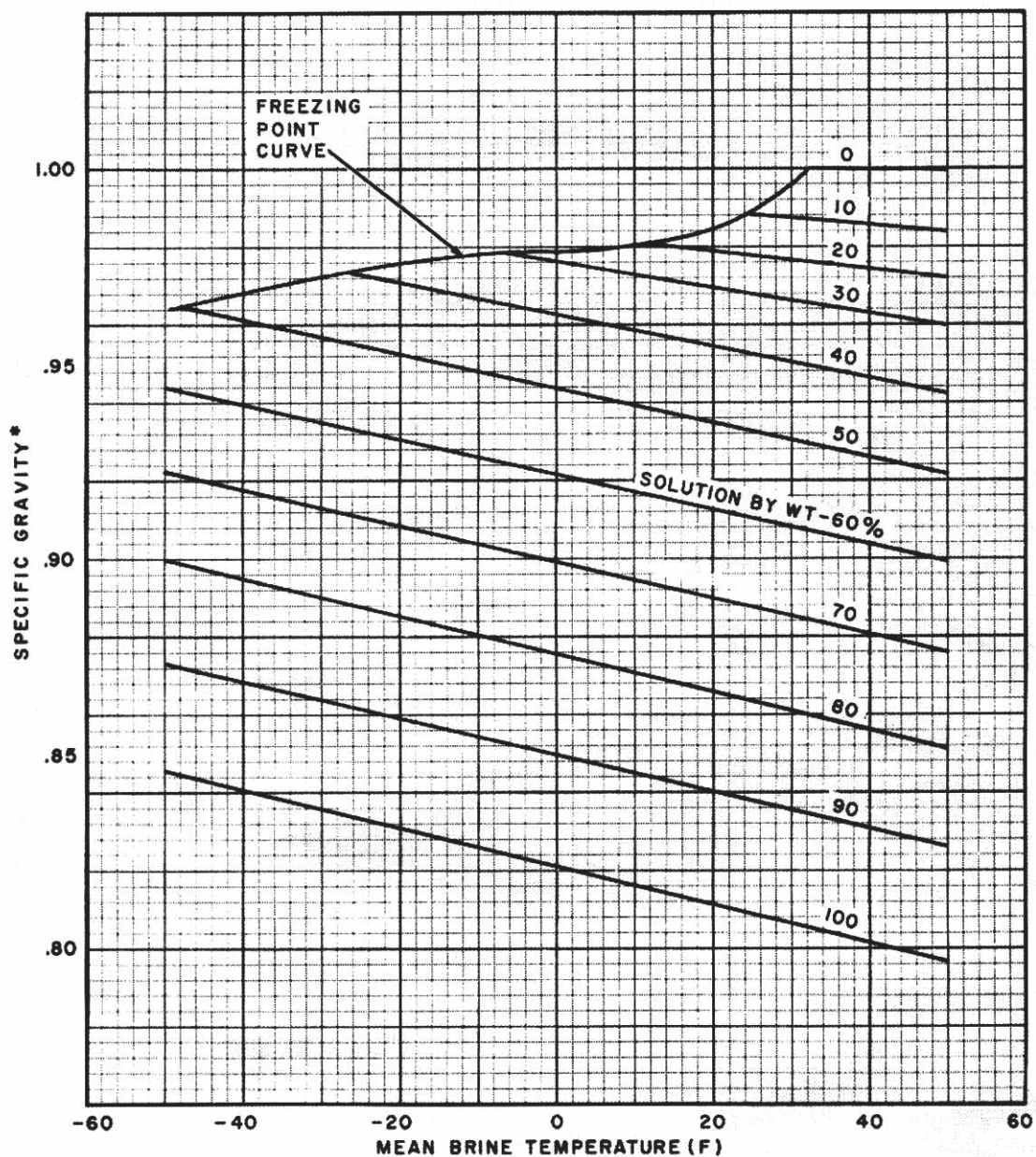




CHART 15-ETHANOL BRINE-SPECIFIC GRAVITY



\*With reference to 60 F water.

Extrapolated values from International Critical Tables



CHART 16-ETHANOL BRINE-SPECIFIC HEAT

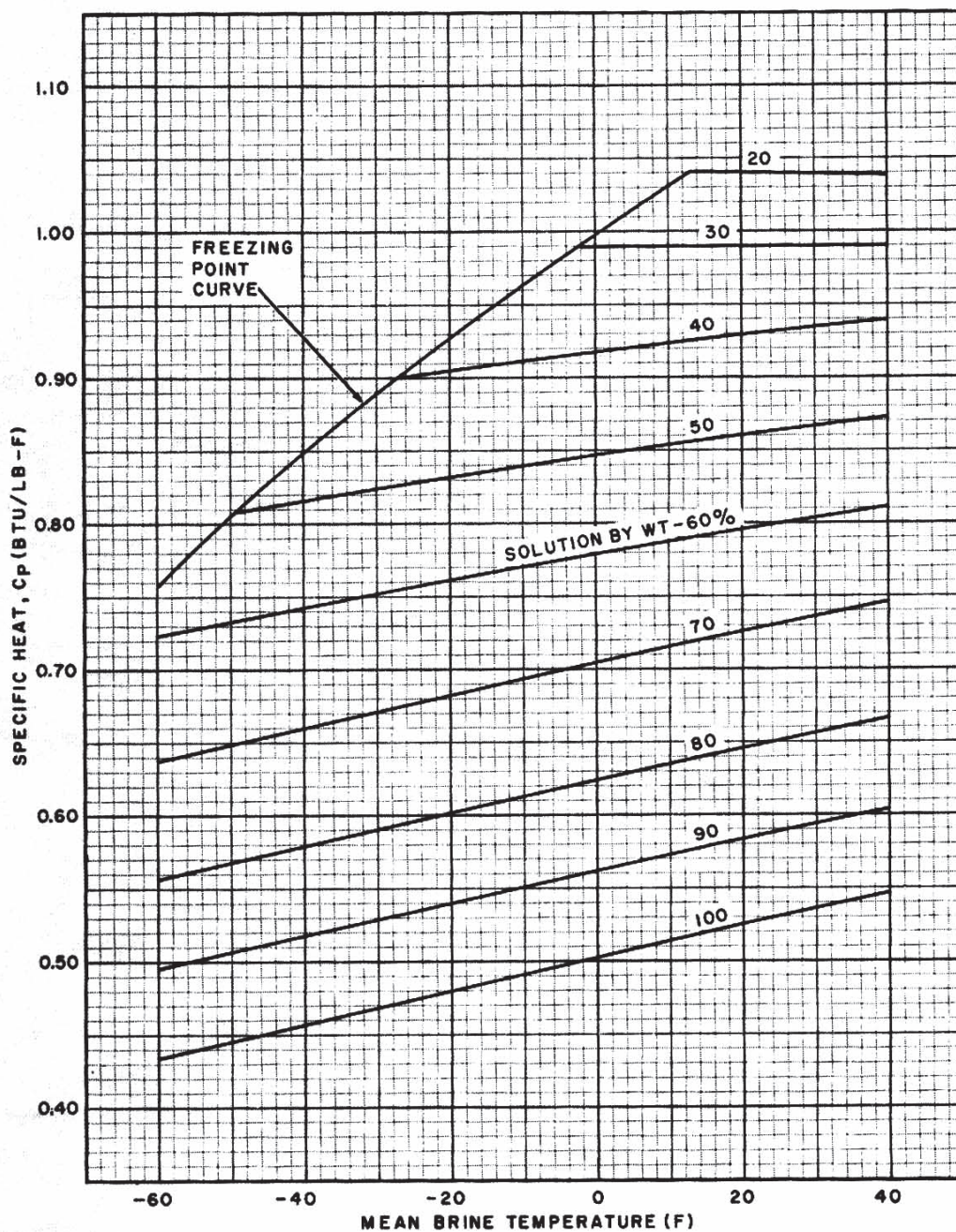




CHART 17-ETHANOL BRINE-THERMAL CONDUCTIVITY

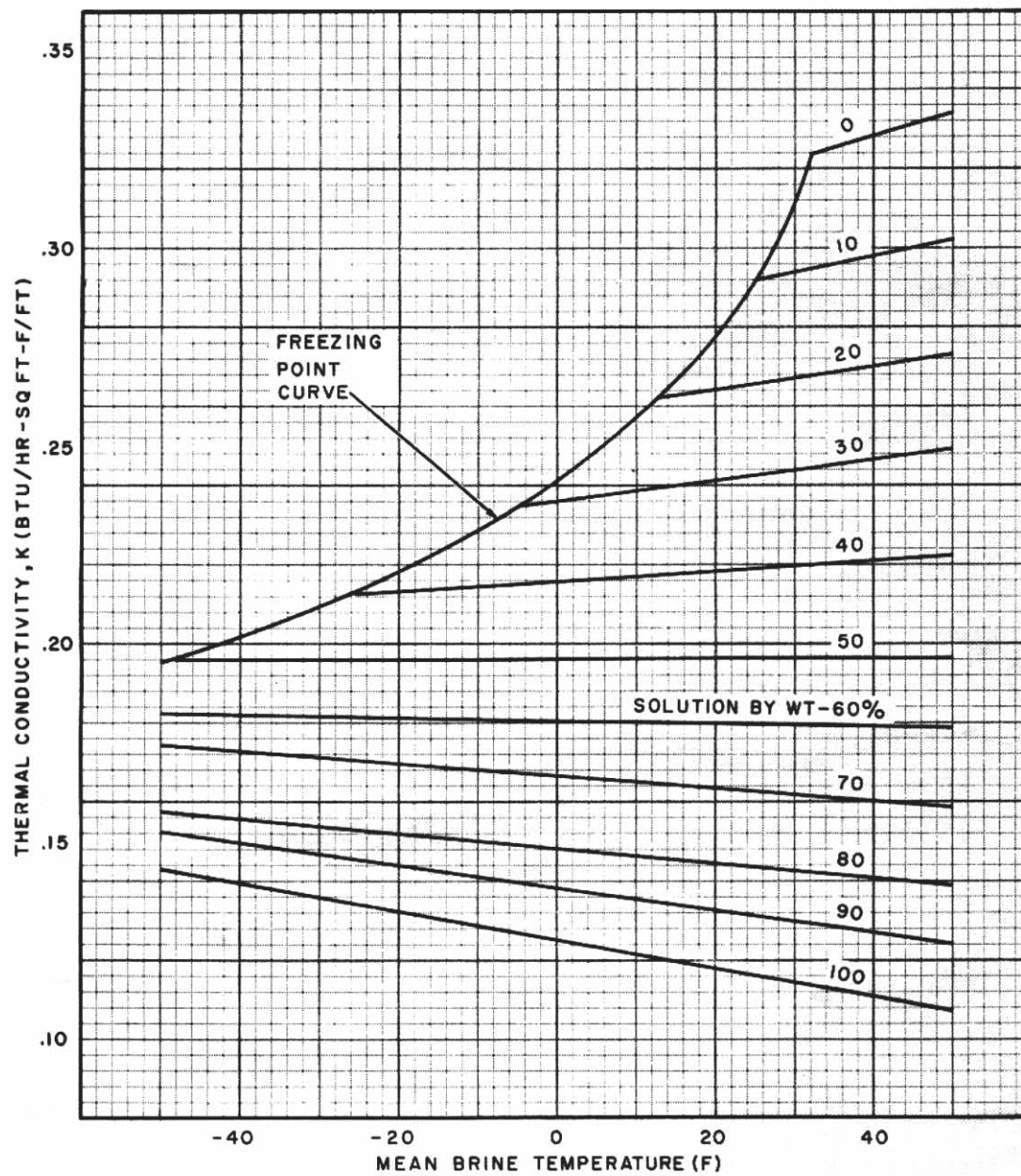
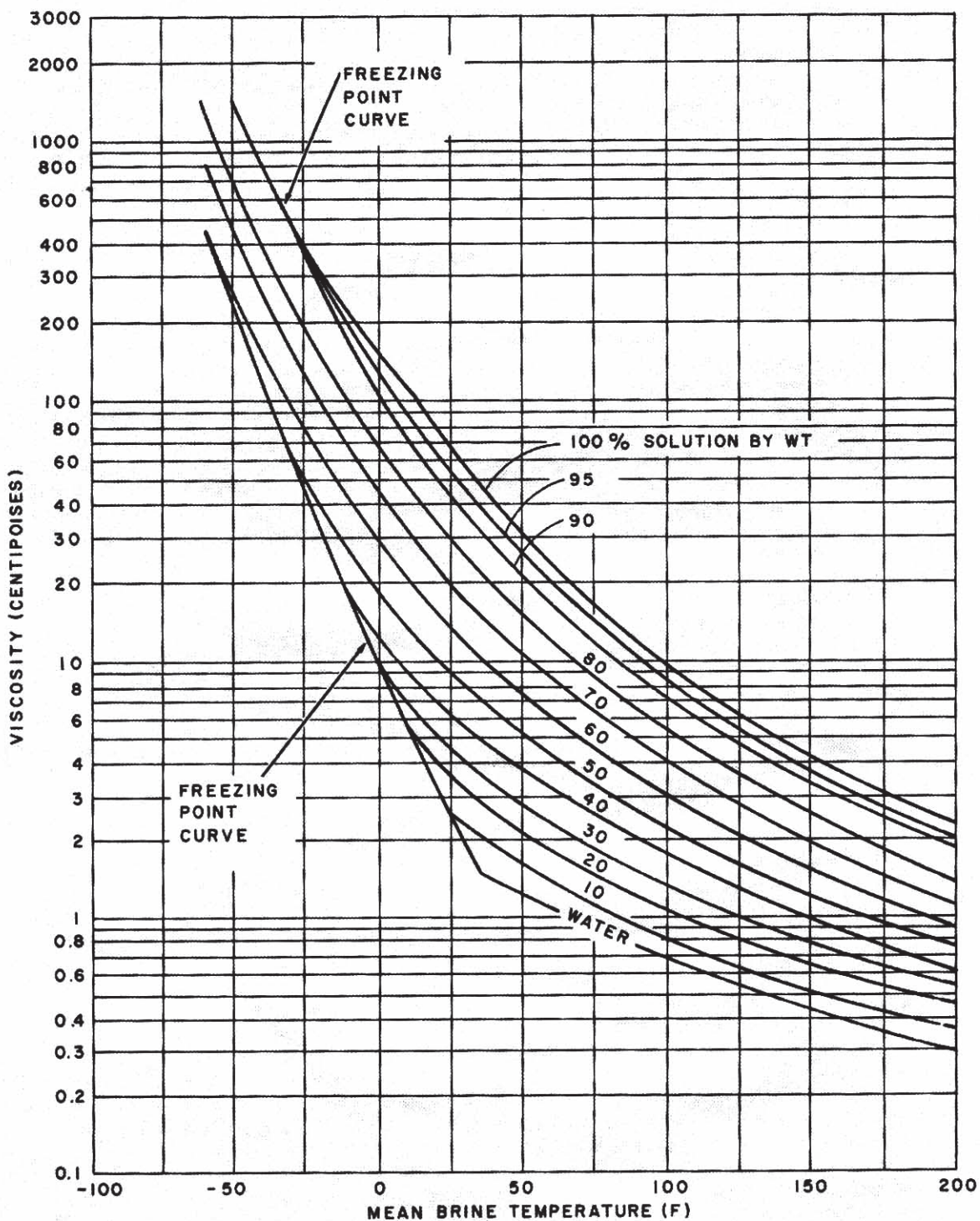




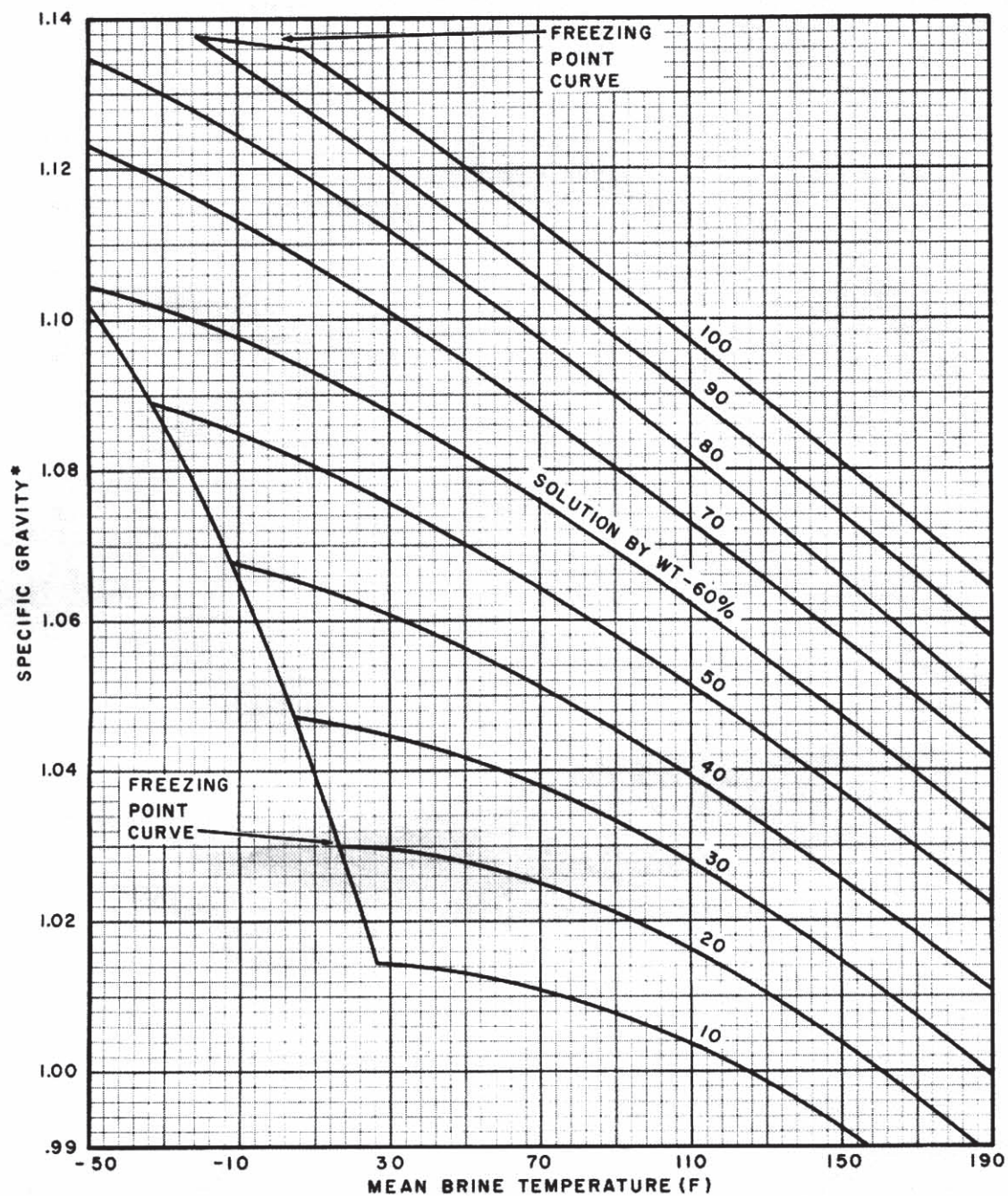
CHART 18-ETHYLENE GLYCOL-VISCOSITY



From *Glycols, Properties and Uses*, Dow Chemical Co. 1961



CHART 19-ETHYLENE GLYCOL-SPECIFIC GRAVITY

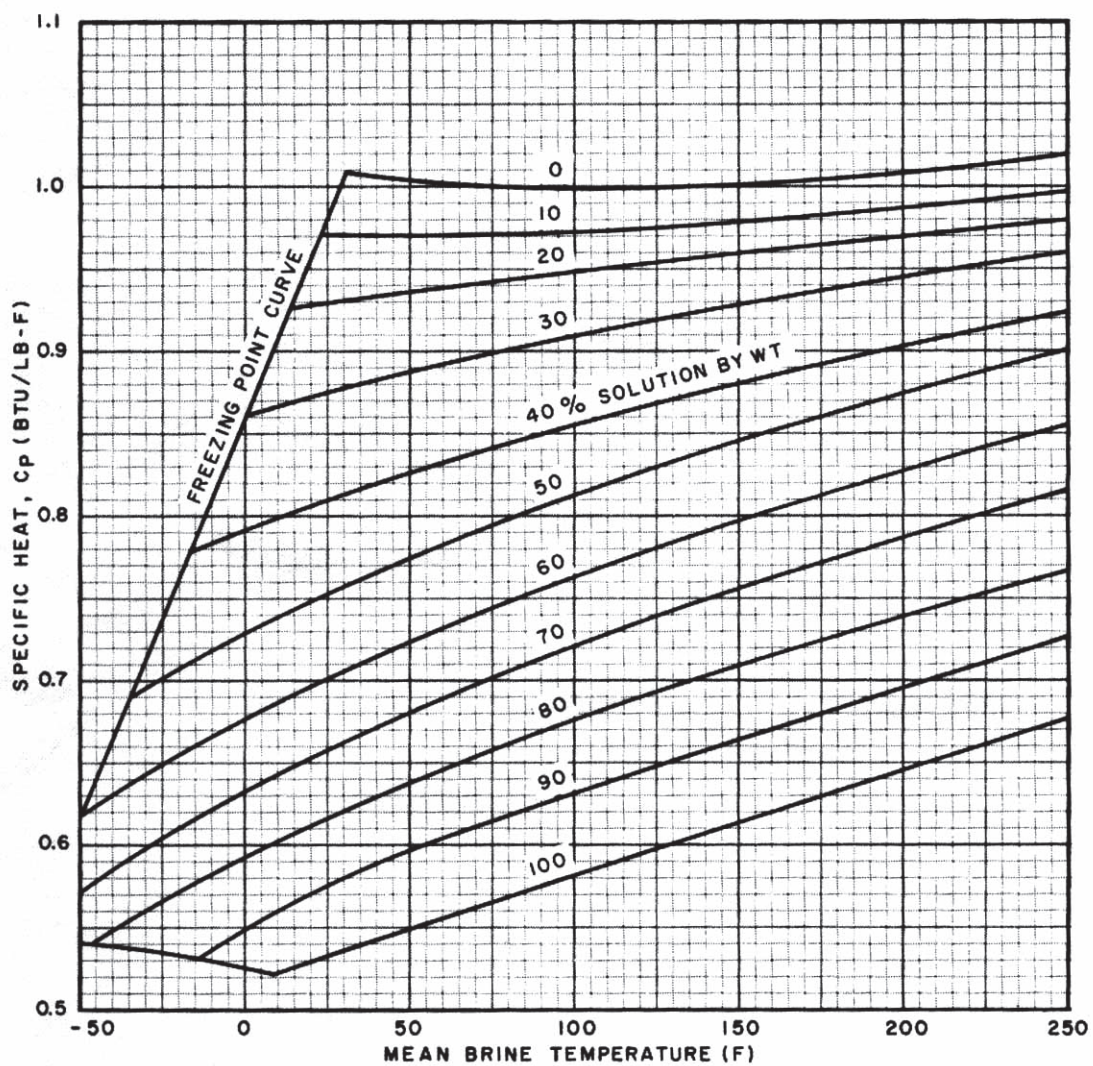


\*With reference to 60 F water.

From *Glycols, Properties and Uses*, Dow Chemical Co. 1961



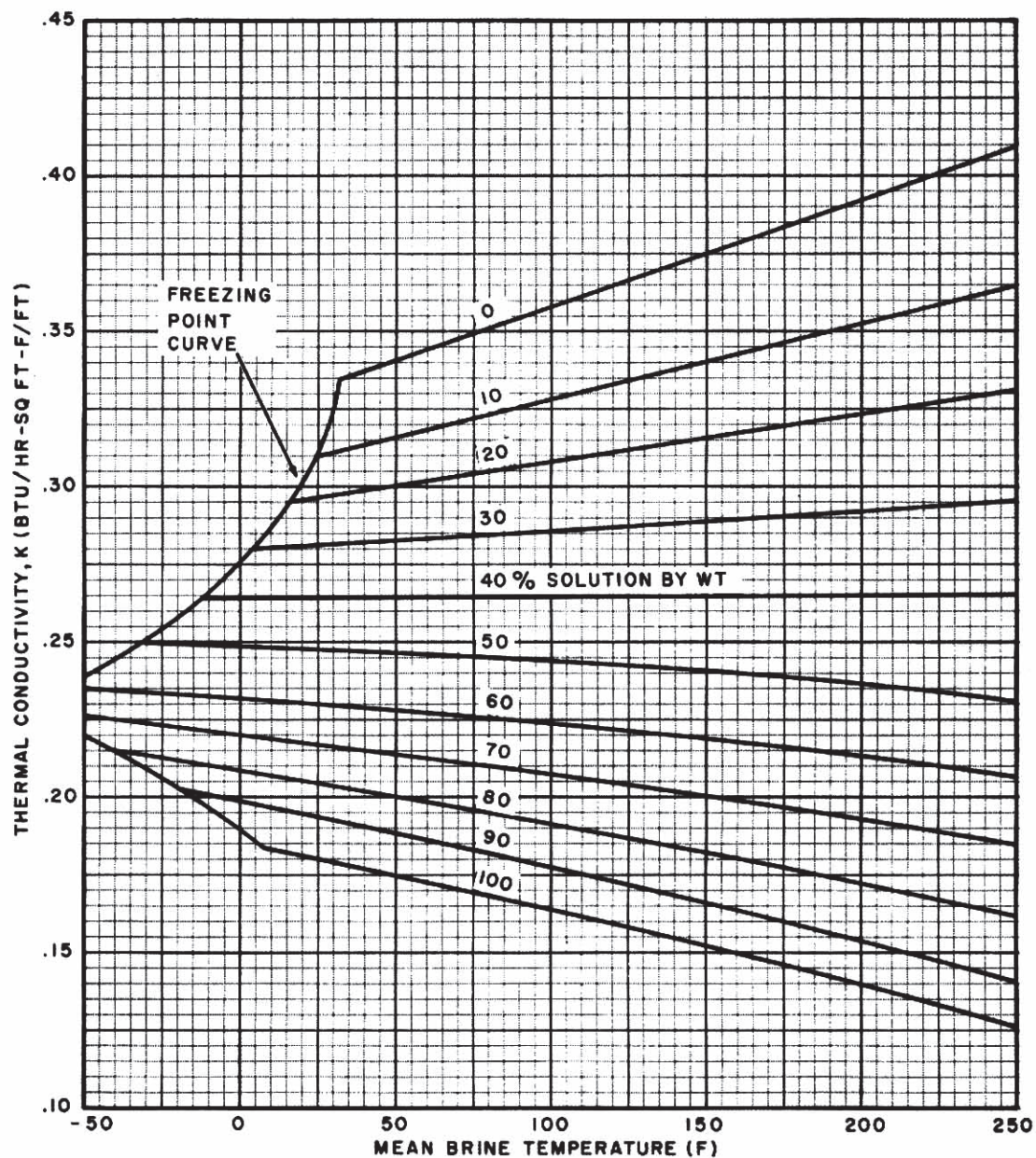
CHART 20-ETHYLENE GLYCOL-SPECIFIC HEAT



From *Glycols*, Union Carbide Chemicals Co. 1958



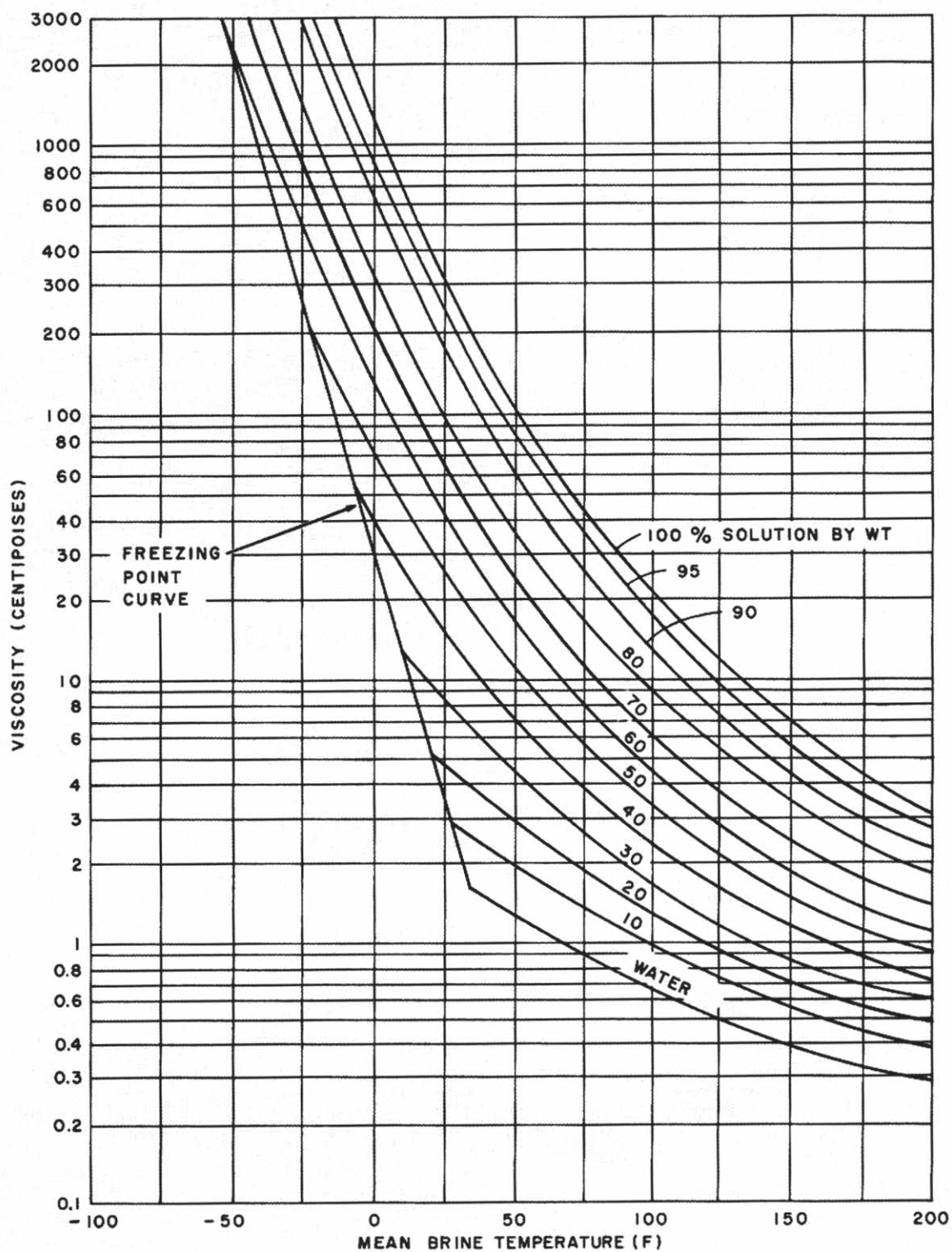
CHART 21-ETHYLENE GLYCOL-THERMAL CONDUCTIVITY



From Glycols, Union Carbide Chemicals Co. 1958

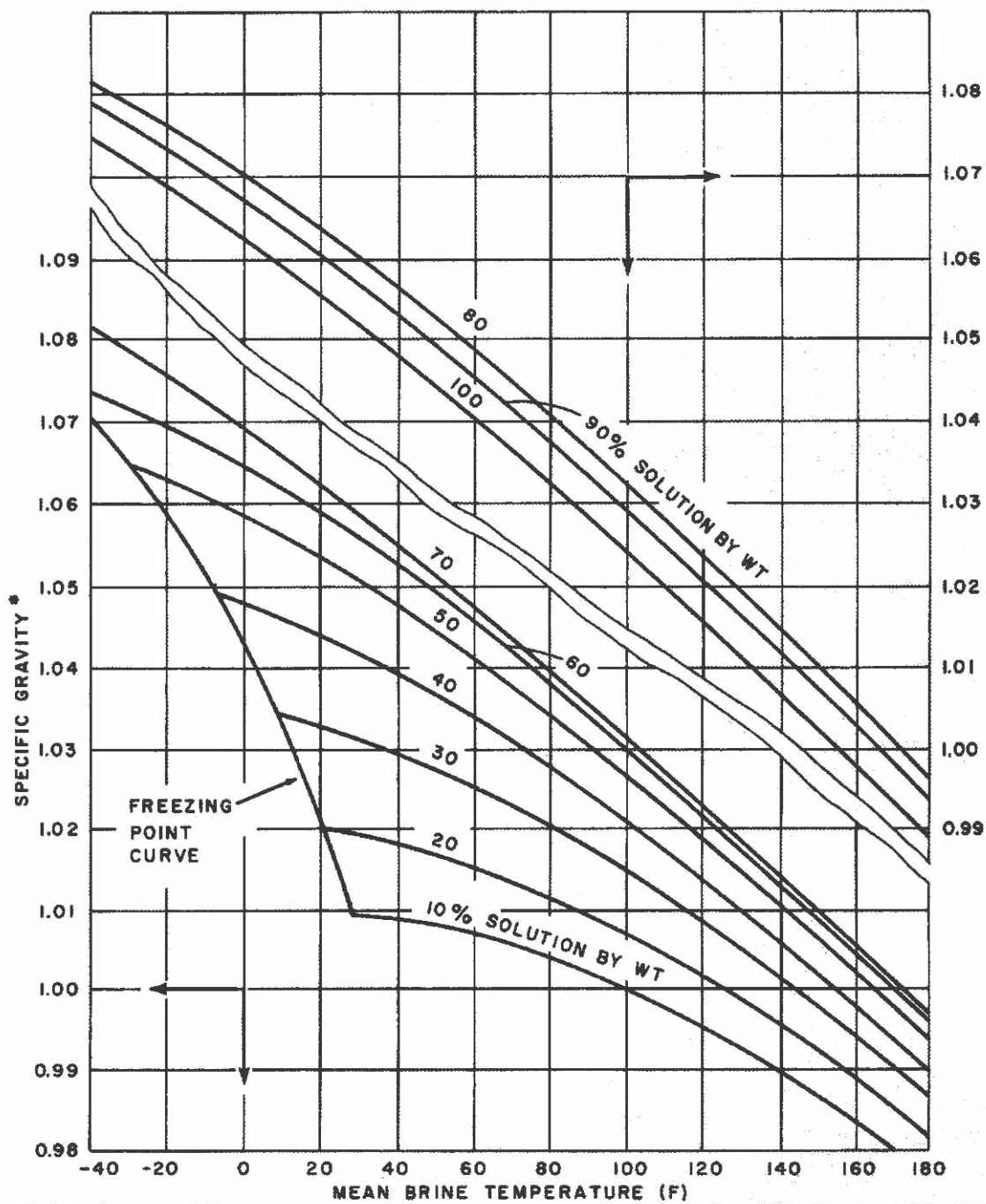


CHART 22-PROPYLENE GLYCOL-VISCOSITY



From Glycols, Properties and Uses, Dow Chemical Co. 1961

CHART 23-PROPYLENE GLYCOL-SPECIFIC GRAVITY

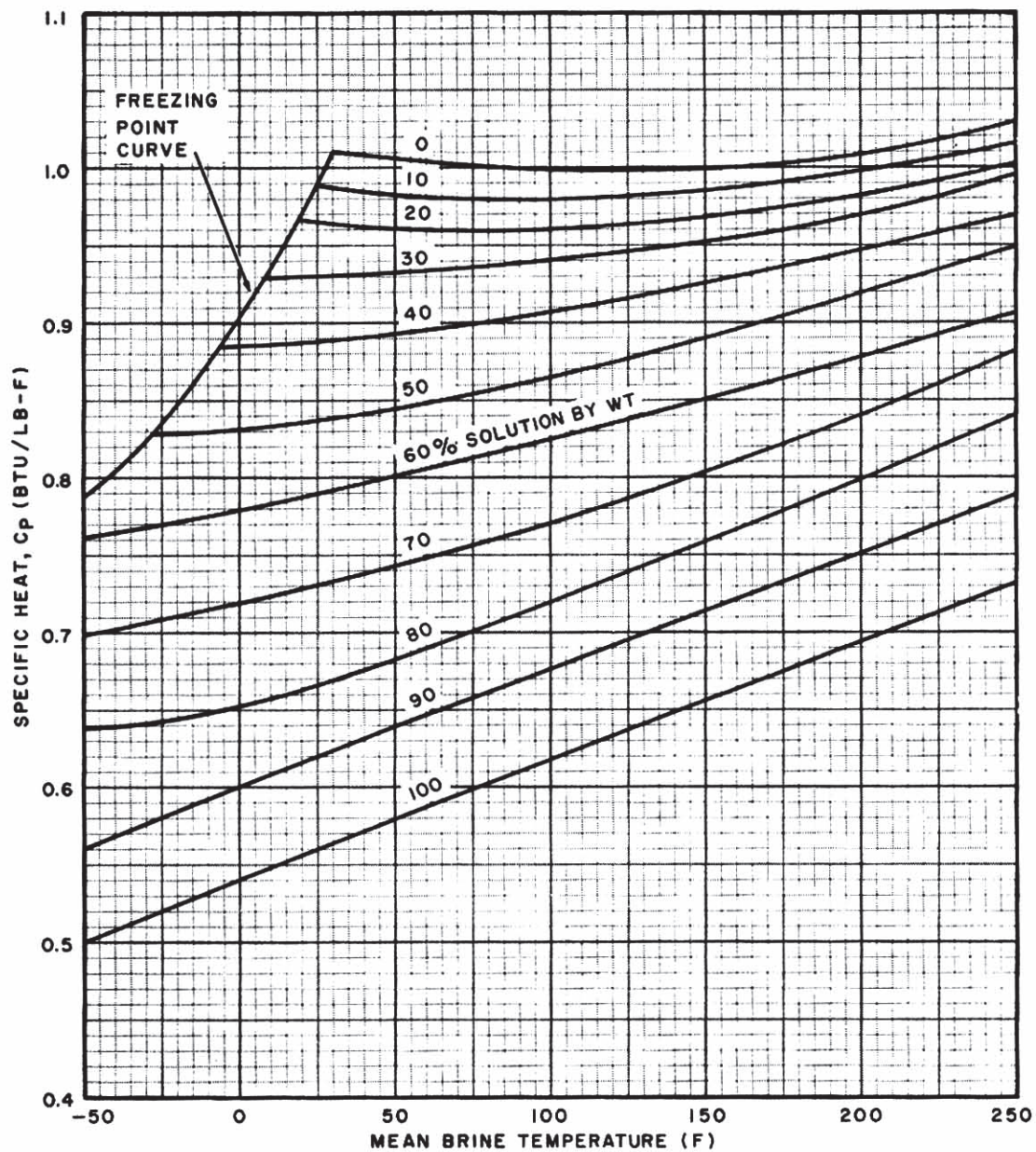


\*With reference to 60 F water.

From Glycols, Properties and Uses, Dow Chemical Co. 1961



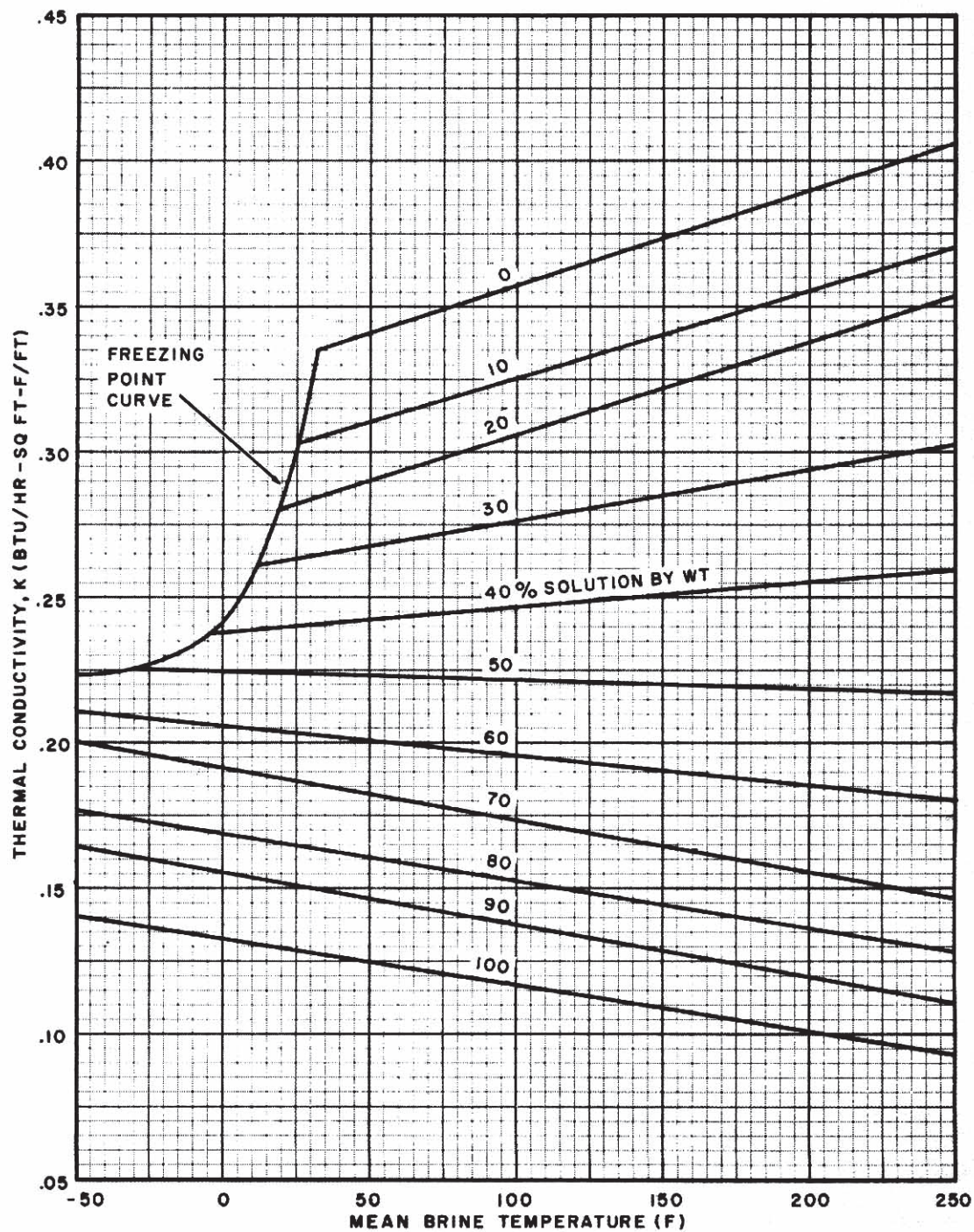
CHART 24-PROPYLENE GLYCOL-SPECIFIC HEAT



From *Glycols*, Union Carbide Chemicals Co. 1958



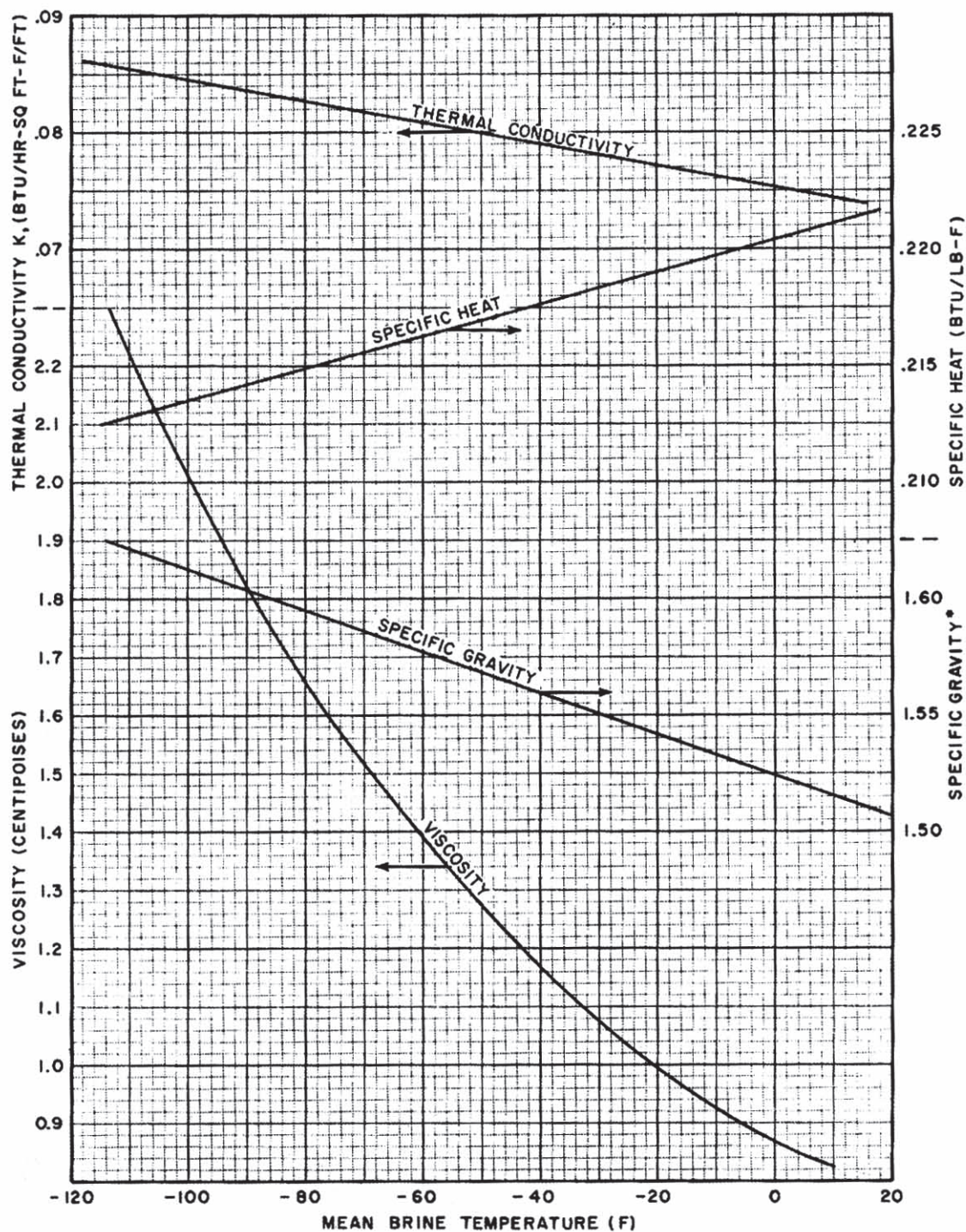
CHART 25-PROPYLENE GLYCOL-THERMAL CONDUCTIVITY



From Glycols, Union Carbide Chemicals Co. 1958



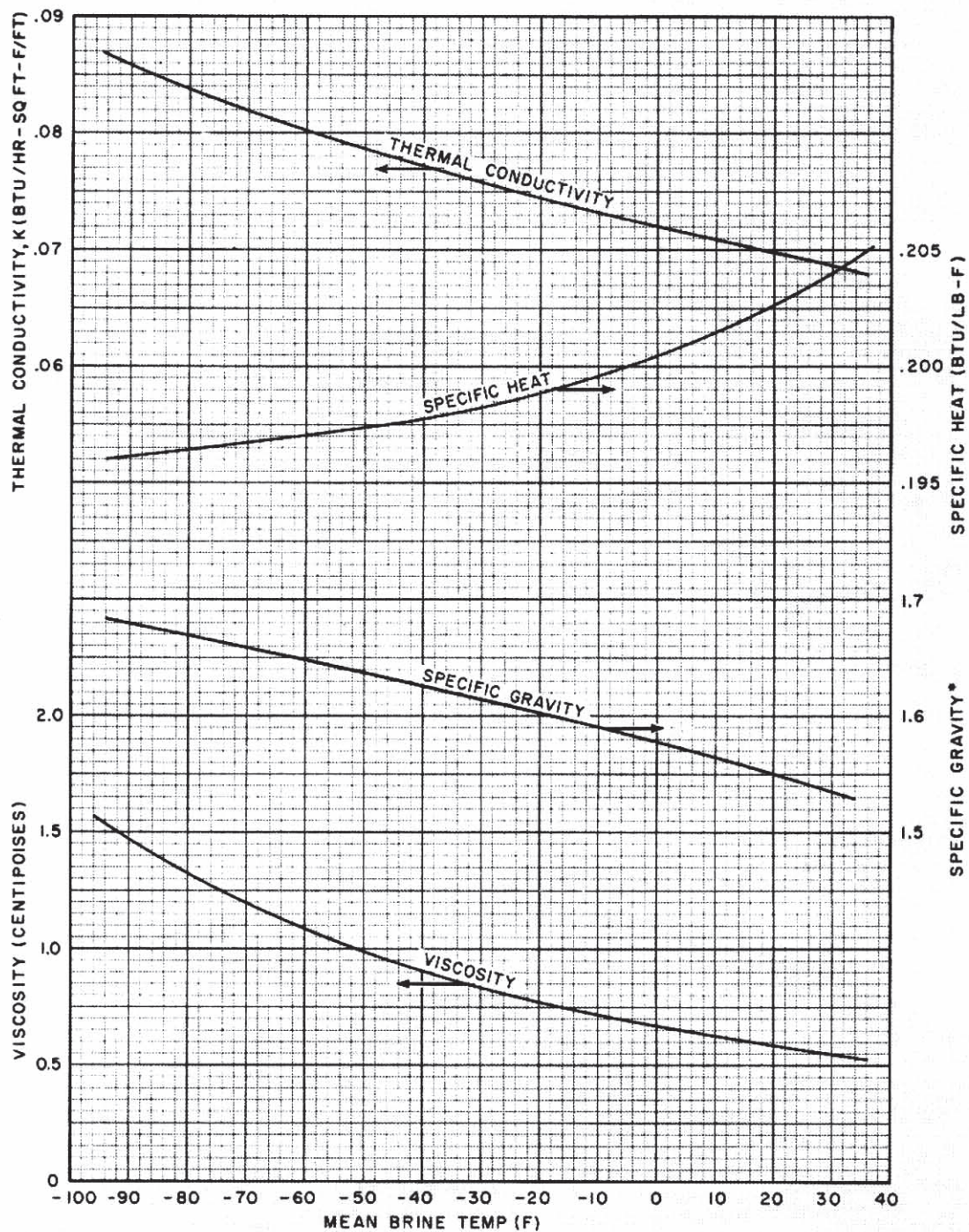
CHART 26-TRICHLOROETHYLENE-PROPERTIES



\*With reference to 60 F water.



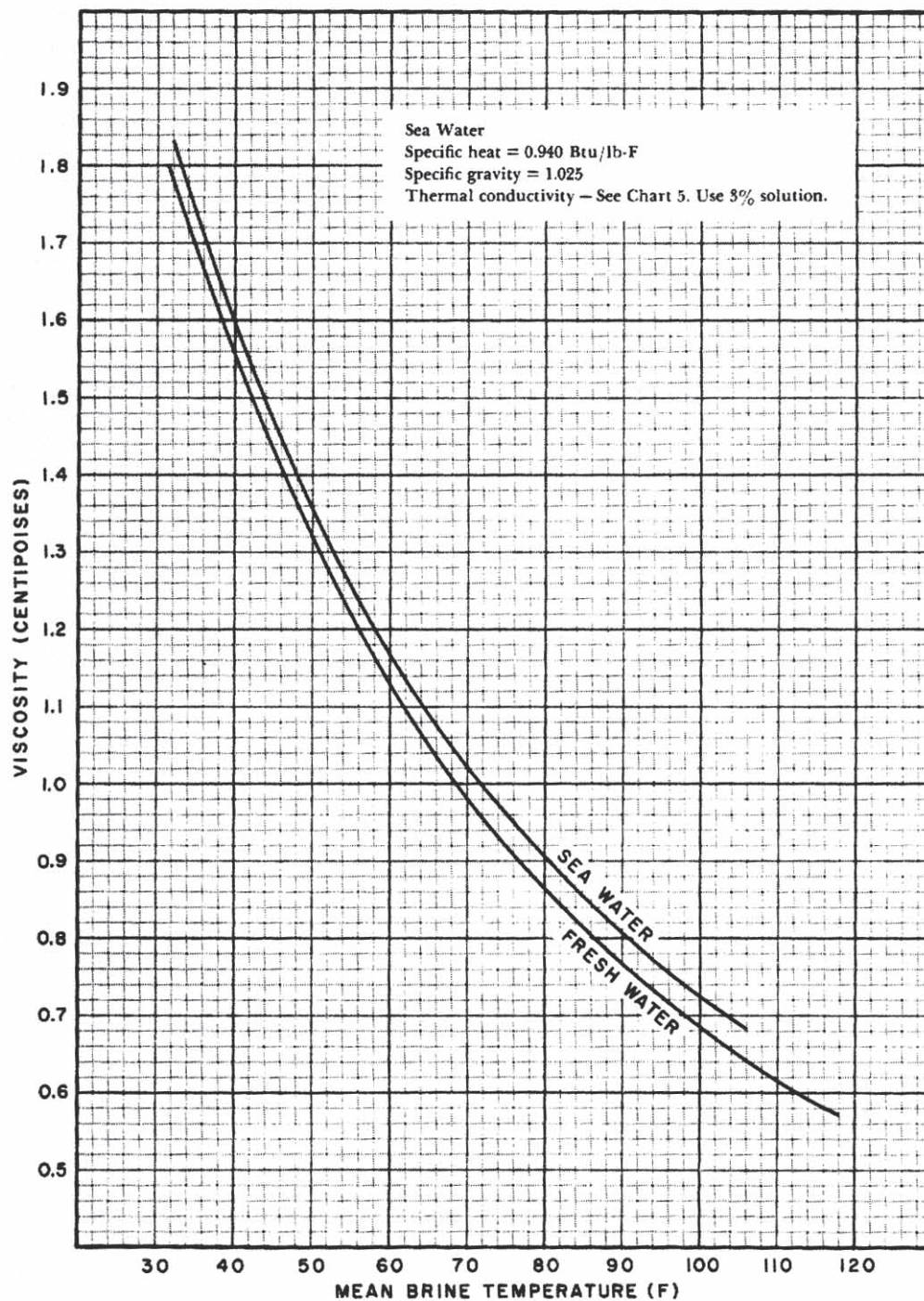
CHART 27-REFRIGERANT 11-PROPERTIES



\*With reference to 60 F water.



CHART 28-WATER-VISCOSITY



## CHAPTER 3. REFRIGERATION OILS

This chapter covers general classification and quality of lubricating oils that are important in refrigeration. The recommendation of oils to be used in a refrigeration system is primarily the responsibility of the refrigeration system manufacturer. However, it is important for an engineer to understand the basis of the selection of these oils in order to properly apply them in the field.

### CLASSIFICATION

Oils classified by source fall in three main groups: animal, vegetable and mineral. Animal and vegetable oils are called fixed oils because they cannot be refined without decomposing. They are unstable and tend to form acids and gums that make them unsuitable for refrigeration purposes.

There are three major classifications of mineral oil: naphthene base, paraffin base, and mixed base. When distilled, a naphthene base oil yields a residue of heavy pitch or asphalt. California oils, some Gulf Coast and heavy Mexican oils are in this class. A paraffin base oil yields a paraffin base oils are Pennsylvania, Northern Louisiana, and parts of Oklahoma and Kansas. The mixed oils contain both naphthene and paraffin bases. Illinois and some mid-continent oils are in this class.

Experience has shown that the naphthene base oils are more suited for refrigeration work for three main reason:

1. They flow better at low temperatures.
2. Carbon deposits from these oils are of a soft nature and can easily be removed.
3. They deposit less wax at low temperatures.

When obtained from selected crudes and properly refined and treated, all three classes of mineral oil can be considered satisfactory for refrigeration use.

### PROPERTIES

To meet the requirements of a refrigeration system, a good refrigeration oil should:

1. Maintain sufficient body to lubricate at high temperature and yet be fluid enough to flow at low temperature.
2. Have a pour point low enough to allow flow at any point in the system.
3. Leave no carbon deposits when in contact with hot surfaces encountered in the system during normal operation.
4. Deposit no wax when exposed to the lowest temperatures normally encountered in the system.
5. Contain little or no corrosive acid.
6. Have a high resistance to the flow of electricity.
7. Have a high flash and fire point to indicate proper blending.
8. Be stable in the presence of oxygen.
9. Contain no sulfur compounds.
10. Contain no moisture.
11. Be light in color, to indicate proper refining.

As lubricating oils for refrigeration compressors are a specialty product, they require consideration apart from normal lubricants. The emphasis in this chapter is on oil used in refrigeration. Do not consider the emphasis as applicable to lubricants in general.



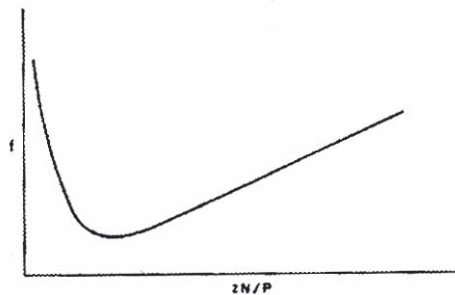


FIG. 12-LUBRICATION CHARACTERISTICS

The characteristics of oil for refrigeration (not necessarily in order of importance) are these:

1. Viscosity
2. Pour point
3. Carbonization
4. Floc point
5. Neutralization
6. Dielectric strength
7. Flash point
8. Fire point
9. Oxidation stability
10. Corrosion tendency
11. Moisture content
12. Color

### VISCOSITY

Viscosity or coefficient of internal friction is that property of a liquid responsible for resistance to flow; it indicates how thick or thin an oil is.

The purpose of an oil is to lubricate bearing or rubbing surfaces. If the oil is too thin, it does not stay between the rubbing surfaces but is forced out, leaving no protective film. If the oil is too thick, it causes drag and loss of power, and may not be able to flow between the bearing or rubbing surfaces.

Friction loss  $f$  is illustrated in *Fig. 12* as a function of viscosity  $z$ , speed  $N$  in revolutions per unit time, and load  $P$  per unit area.

Viscosity is usually measured in terms of Saybolt Seconds Universal (SSU). Under standard temperature conditions, oil is allowed to flow thru a carefully calibrated orifice until a standard volume has passed. The number of seconds necessary for the given volume of oil to flow thru the orifice is the viscosity of the oil in Saybolt Seconds Universal. The higher the viscosity, the more

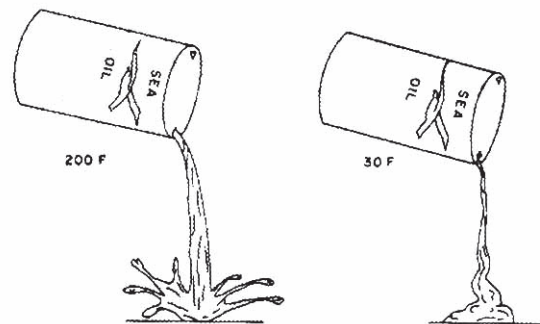


FIG. 13-EFFECT OF TEMPERATURE ON VISCOSITY

seconds it takes to pass thru the hole, or the higher the viscosity, the thicker the oil.

Viscosity is affected by temperature (*Fig. 13*), thus making it an important characteristic of refrigeration oils. The viscosity increases as the temperature decreases, or the lower the temperature the thicker the oil. In low temperature applications, this thickening of oil with its increasing resistance to flow is a major problem. As low temperatures occur in the evaporator, an oil that is too viscous thickens and may stay in the evaporator, thus decreasing the heat transfer and possibly creating a serious lack of lubrication in the compressor.

Oil may thin out or become less viscous at high temperatures. Too warm a crankcase may conceivably thin the oil to a point where it can no longer lubricate properly. A refrigeration oil must maintain sufficient body to lubricate at high temperatures and yet to be fluid enough to flow at low temperatures. Oil should be selected which has the lowest viscosity possible to do the assigned job.

Viscosity is also affected by the miscibility of the oil and the refrigerant. The miscibility of oil and refrigerants varies from almost no mixing (with Refrigerant 717, ammonia) to complete mixing (with some halogenated hydrocarbons such as Refrigerant 12).

Refrigerant 717 has almost no effect on the viscosity of a properly refined refrigeration oil. As it is not miscible, there is no dilution of oil and therefore no change in viscosity.

In the case of miscible refrigerants such as Refrigerant 12, the refrigerant mixes with and dilutes the oil, and lubrication must be performed by this mixture. This mixing reduces the viscosity of the oil.

## CHART 29-OIL-REFRIGERANT VISCOSITY

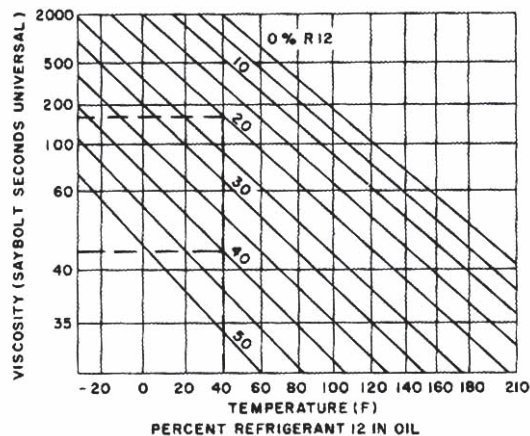


Chart 29 shows viscosity change for mixtures of oil and Refrigerant 12. For example, oil at 40 F containing 20% Refrigerant 12 by weight has a viscosity of approximately 150 SSU.

When the amount of Refrigerant 12 is increased to 40%, the SSU is reduced to 45.

When oil and refrigerants are miscible, the oil is carried thru the system by the refrigerant. It is imperative that the oil be returned to the compressor. Keeping low side gas velocity up assures this proper oil return. With a completely miscible refrigerant, the oil is diluted sufficiently even at low temperatures to keep the viscosity low and to allow the oil to return easily with the refrigerant to the compressor.

There is a third group of refrigerants whose miscibility with oil varies. For example, Refrigerant 22 is completely miscible with oil at high temperatures, but at low temperatures it separates into two layers with the oil on top. When designing or selecting equipment for this group of refrigerants, great care must be taken to allow for low temperature separation of oil and refrigerant.

Oil separation in a flooded cooler necessitates the use of an oil bleed line from the bottom of the cooler to the suction loop. Because the oil is lighter than Refrigerant 22 and floats on top of the liquid refrigerant, an auxiliary oil bleed line from the side of the cooler is required.

**POUR POINT**

The pour point of an oil is that temperature at which it ceases to flow.

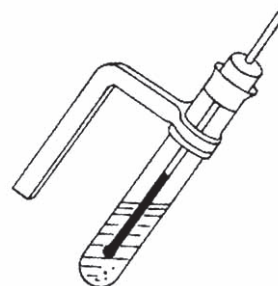


FIG. 14-POUR POINT TUBE

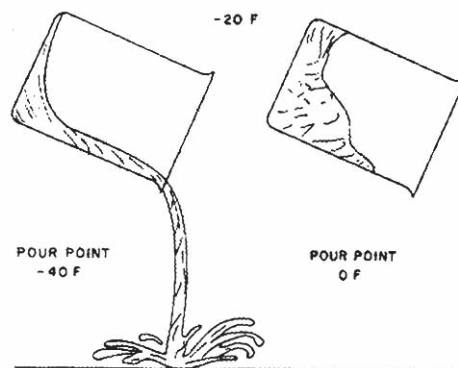


FIG. 15-POUR POINT

Pour point is simple to determine. Using the apparatus shown in the Fig. 14, the selected batch of oil is slowly cooled under test condition until the oil no longer flows. This temperature is the pour point.

Figure 15 shows two oils with different pour points which have been cooled to the same temperature (-20 F). On the left the oil with a -40 F pour point flows freely. On the right the oil with the 0 F pour point does not flow.

Pour point depends on the wax content and/or viscosity.

With all refrigerants some oil is passed to the evaporator. Regardless of how small an amount, this oil must be returned to the compressor. In order that it may be returned, it must be able to flow thruout the system.

Oil pour point is very important with nonmiscible and partly miscible refrigerants; with the miscible refrigerants the viscosity of the oil refrigerant mixture assumes greater importance as shown in Chart 29, Oil-Refrigerant Viscosity.



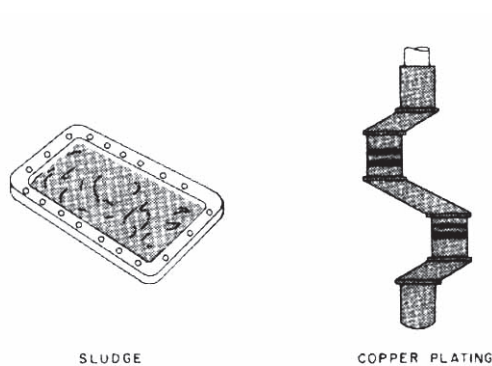


FIG. 16-CARBON DEPOSIT

### CARBONIZATION

All refrigeration oils can be decomposed by heat. When such action takes place, a carbon deposit remains.

Carbonization properties of an oil are measured by the Conradson Carbon Value. This value is found by heating and decomposing an oil until only the carbon deposit remains. The ratio of the weight of the carbon deposit to the weight of the original oil sample is the Conradson Carbon Value.

Hot surfaces within the refrigeration system sometimes decompose the oil. The carbon remaining is hard and adhesive in paraffin base oils, and forms sludge.

Naphthene base oils form a light fluffy carbon which, though a contaminant, is not as damaging as the hard carbon. However, neither type of carbon deposit is desirable as there is some indication that a relationship exists between oil breakdown, carbonization and copper plating (*Fig. 16*).

A good oil should not carbonize when in contact with hot surfaces encountered in the system during normal operation. A refrigeration oil should have as low a Conradson Carbon Value as practical.

### FLOC POINT

All refrigeration oils contain some wax though the amount varies considerably. As the temperature of the oil decreases, the solubility of the wax also decreases. When there is more wax present than the oil can hold, some separates and precipitates.

The method used to determine the waxing tendencies of a refrigeration oil is the floc test (*Fig. 17*). A mixture of 10% oil and 90% Refrigerant 12 in a clear container is cooled until the wax starts to separate, turning the mixture cloudy. As cooling continues, small

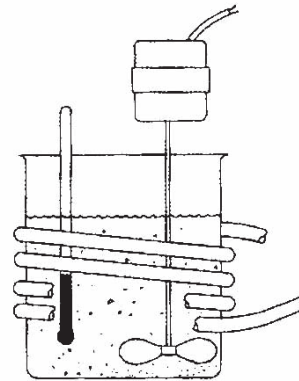


FIG. 17 – FLOC TEST

clusters of wax form. The temperature at which these clusters are first noticeable to the unaided eye is the floc point.

The free wax that is formed when a refrigeration oil is cooled can clog metering devices and restrict flow.

Wax normally deposits out in the colder parts of the system such as in the evaporator and its metering device (*Fig. 18*). Wax in the evaporator causes some loss of heat transfer; wax in the metering device can cause restriction or sticking.

A good refrigeration oil should not deposit wax when exposed to the lowest temperatures normally encountered in the refrigeration system.

### NEUTRALIZATION

Almost all refrigeration oils have some acid tendencies. Nearly all oil contains material of uncertain composition referred to as organic acids. These are

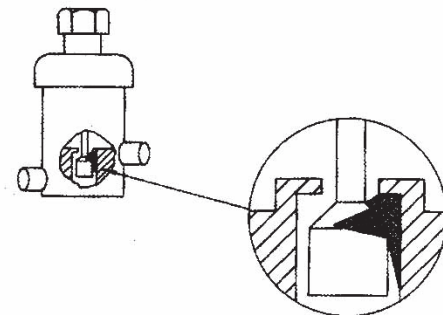


FIG. 18-WAX DEPOSITS

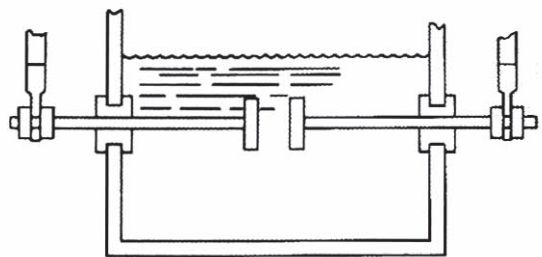


FIG. 19-DIELECTRIC TESTING

usually harmless and should not be confused with mineral acids which are harmful.

The neutralization number is a measure of the amount of mineral acid, and is determined by measuring the amount of test fluid that must be added to the oil to bring it to a neutral condition. A low neutralization number means that few acids are contained in the oil.

Improper refining may leave a large proportion of corrosive acid present in an oil. A low neutralization number indicates a low acid content. Acids may corrode interior parts of the system; they react with motor insulation and other materials to form sludge which can eventually cause a complete system breakdown. A low neutralization number is highly desirable in refrigeration oils.

### DIELECTRIC STRENGTH

Dielectric strength is a measure of the resistance of an oil to the passage of electric current. It is measured in kilovolts on a test cell as shown in *Fig. 19*. The poles in the cell are a predetermined distance apart. They are immersed in the oil so that current must pass thru the oil to flow from one pole to the other. The kilovolts necessary to cause a spark to jump this gap is known as the dielectric rating. Good refrigeration oils normally have a rating of over 25 kilovolts.

A dielectric rating is important because it is a measure of impurities in the oil. If the oil is free of foreign matter, it has a high resistance to current flow. If the oil contains impurities, its resistance to current flow is low.

The presence of foreign matter in a refrigeration system is sufficient reason for considering this test valuable. Hermetic motors make a high kilovolt rating necessary for refrigeration oils since a low kilovolt rating may be a contributing factor to shorted windings.

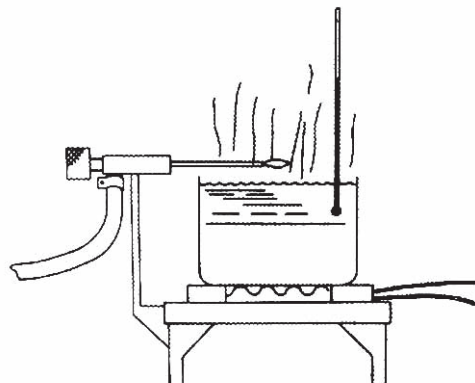


FIG. 20-FLASH AND FIRE POINT TESTS

### FLASH POINT AND FIRE POINT

The flash point of an oil is that temperature at which oil vapor flashes when exposed to a flame. The fire point is that temperature at which it continues to burn.

The apparatus shown in *Fig. 20* heats the oil while a small gas flame is passed closely over the surface of the oil. When a flash of fire is noted at some point on the surface, the flash point has been reached. The apparatus continues to heat the oil until it ignites and continues to burn. This is the fire point.

The flash point of a good refrigeration oil is well over 300 F. Temperatures obtained in the normal refrigeration system rarely reach this point. The test for flash and fire points is important as it is a means of detecting inferior blends.

It is possible to get an acceptable viscosity reading for a refrigerant oil by mixing a small amount of high viscosity oil with a large amount of low viscosity oil. The viscosity of the mixture indicates a satisfactory oil when actually the low viscosity oil is inferior and breaks down under normal use. Fortunately, this can be detected using the flash and fire point test which indicates the inferiority of the low viscosity oil.

### OXIDATION STABILITY

Oxidation stability is the ability of refrigeration oil to remain stable in the presence of oxygen. The Sligh Oxidation Test is used to determine this stability (*Fig. 21*).

While exposed to oxygen in the flask, the oil is heated to a high temperature for an extended period of time. The solid sludge that is formed in the flask is weighed and



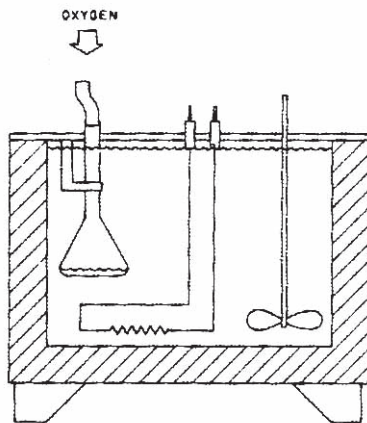


FIG. 21-SLIGH OXIDATION TEST

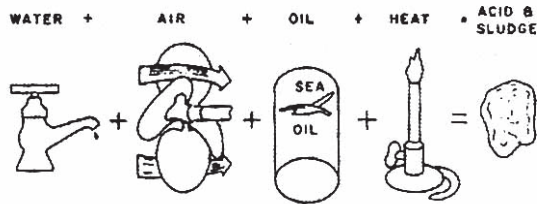


FIG. 22-OIL BREAKDOWN

reported as the Sligh Oxidation Number.

When air enters a system, some moisture generally accompanies it. The combination of moisture, air, refrigeration oil and discharge temperatures produces acid which creates sludge (Fig. 22). If oil has a low Sligh Oxidation Number, the oil breakdown to acid and sludge is quite slow.

### CORROSION TENDENCY

The corrosion tendency of a refrigeration oil is measured by the copper strip corrosion test (Fig. 23). This test is intended to indicate the presence of undesirable sulfur compounds in the refrigeration oil.

A strip of polished copper is immersed in an oil sample in a test tube. This is subjected to temperatures around 200 F. After about 3 hours, the copper is removed from the oil, cleaned with a solvent, and examined for discoloration. If the copper is tarnished or pitted, then sulfur is present in the oil. Well refined oils

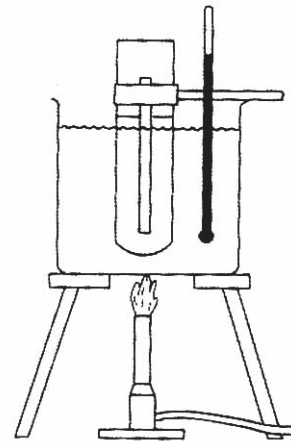


FIG. 23-CORROSION TEST

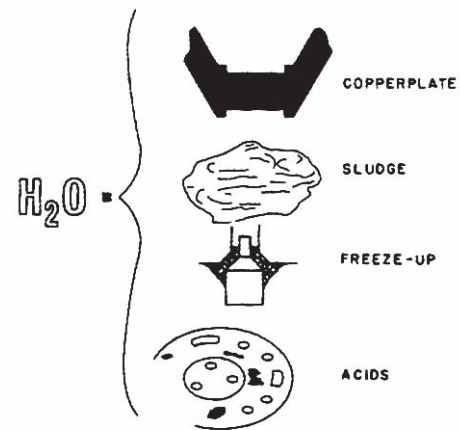


FIG. 24-MOISTURE AND AIR IN THE SYSTEM

rarely cause more than a slight tarnishing of copper in this test.

A good refrigeration oil should score negative in the copper strip corrosion test. If it does not, it contains sulfur in a corrosive form.

Sulfur alone is a deadly enemy of the refrigeration system but, in the presence of moisture, sulfurous acid is formed, one of the most corrosive compounds in existence. Though the sulfurous acid converts immediately to sludge, this sludge is certain to create serious mechanical problems.

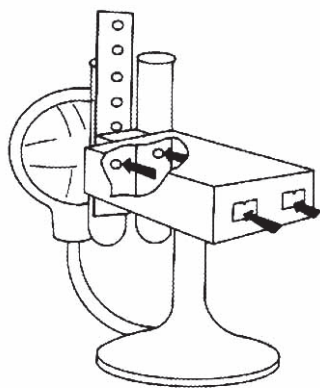


FIG. 25-COLOR TESTING

## MOISTURE CONTENT

Moisture in any form is an enemy of the refrigeration system; moisture contributes to copper plating, formation of sludges and acids, and can cause freezeup (*Fig. 24*). No refrigeration oil should contain enough moisture to affect the refrigeration system.

## COLOR

The color of a refrigeration oil is expressed by a numerical value that is based on comparison of the oil with certain color standards. This is done with the colorimeter shown in *Fig. 25*.

The color of a good refrigeration oil should be light but not water white. Continual refining of a lubricating oil results in a water white color. It also results in poor lubricating qualities.

Under-refining leaves a high content of unsaturated hydrocarbons which darken and discolor an oil. These are believed to be the constituents in oil that act as a solvent for copper. Therefore, the aim is to refine the oil sufficiently to remove these hydrocarbons but not so much as to destroy the lubricating quality.

## SPECIFICATIONS

1. For open and hermetic reciprocating compressors at standard air conditioning levels, the following oil characteristics are typical:
  - Viscosity,  $150 \pm 10$  SSU at 100 F
  - 40 to 45 SSU at 210 F
  - Dielectric (min.), 25 kv
  - Pour Point (max.), -35 F
  - Flash Point (min.), 330 F
  - Neutralization Number (max.), .05
  - Floc Point (max.), -70 F
2. For centrifugal compressors used for water cooling at air conditioning levels, the following are typical properties:
  - Viscosity,  $300 \pm 25$  SSU at 100 F
  - 50 to 55 SSU at 210 F
  - Dielectric (min.), 25 kv
  - Pour Point (max.), 20 F
  - Flash Point (min.), 400 F
  - Neutralization Number (max.), 0.1
3. For special applications, consult the equipment manufacturer.





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